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Kobayashi et al.

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(45) **Date of Patent: Jun. 8, 2004**

(54) MULTINOZZLE INK JET RECORDING DEVICE CAPABLE OF IDENTIFYING DEFECTIVE NOZZLE

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(22) Filed: **Sep. 21, 2001**

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(30) **Foreign Application Priority Data**

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(51) **Int. Cl.**^{7} **B41J 2/165**
(52) **U.S. Cl.** **347/23**; 347/19
(58) **Field of Search** 347/23, 19, 37, 347/40, 43, 76, 77, 44

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(57) ABSTRACT

When ink droplets are ejected, angled or splashed where a plurality of minute ink droplets are generated, angled or splashed ink clings on an electrode 401, 402 and increases the amount of electric current conducted therethrough. Hence, the defectiveness of ink ejection can be detected by monitoring the amount of the electric current. When the defectiveness of ink ejection is detected, ejection data D is retrieved and updates the ejection data D based on a condition register S, and set to a defect register E. When the defect register E has only one element that takes a condition value of 1 indicating defectiveness, the corresponding nozzle is identified as defective. The restoring means reallocates dots, which have been originally allocated to the defective nozzle, to neighboring nozzle.

20 Claims, 11 Drawing Sheets

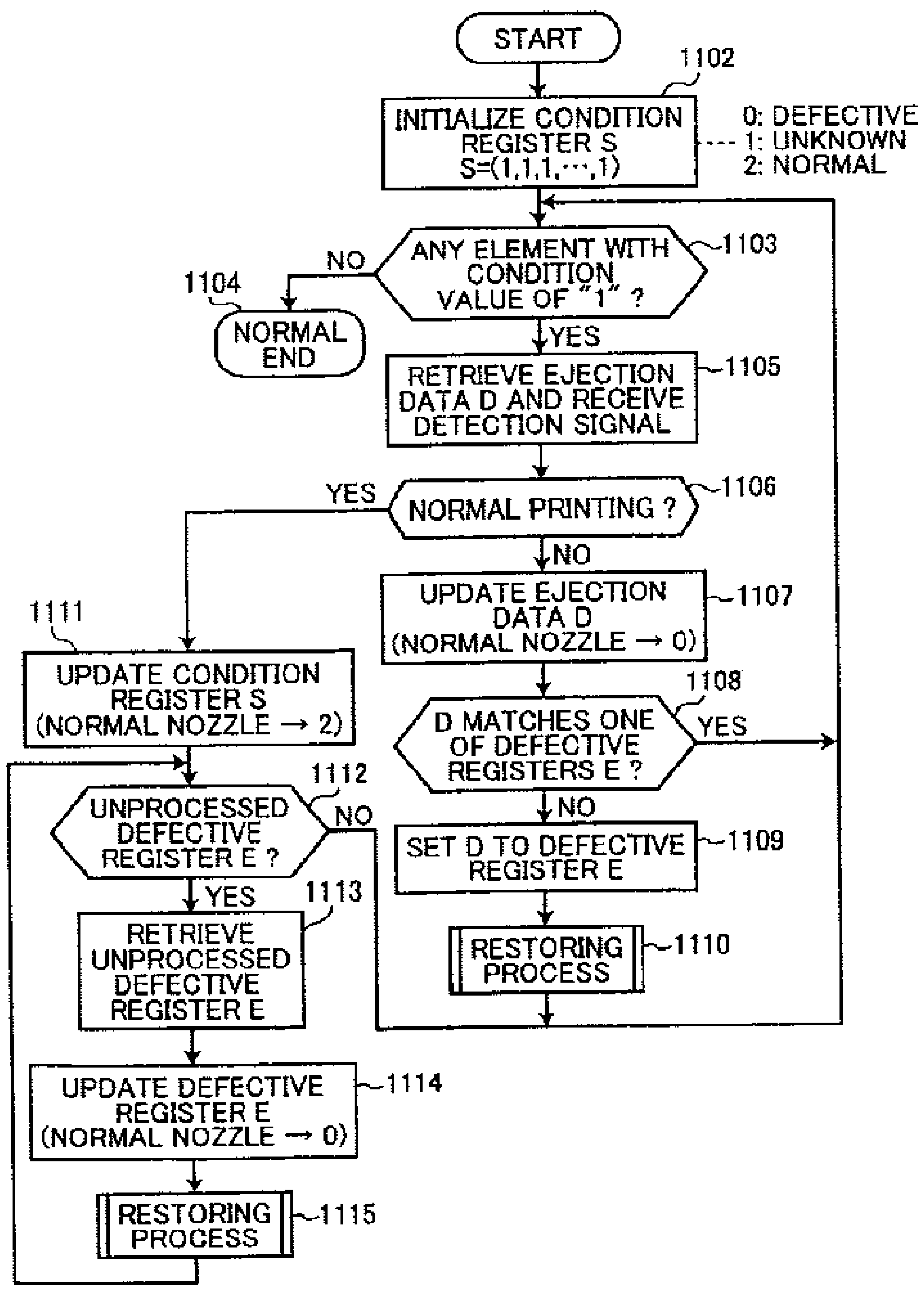


FIG. 1

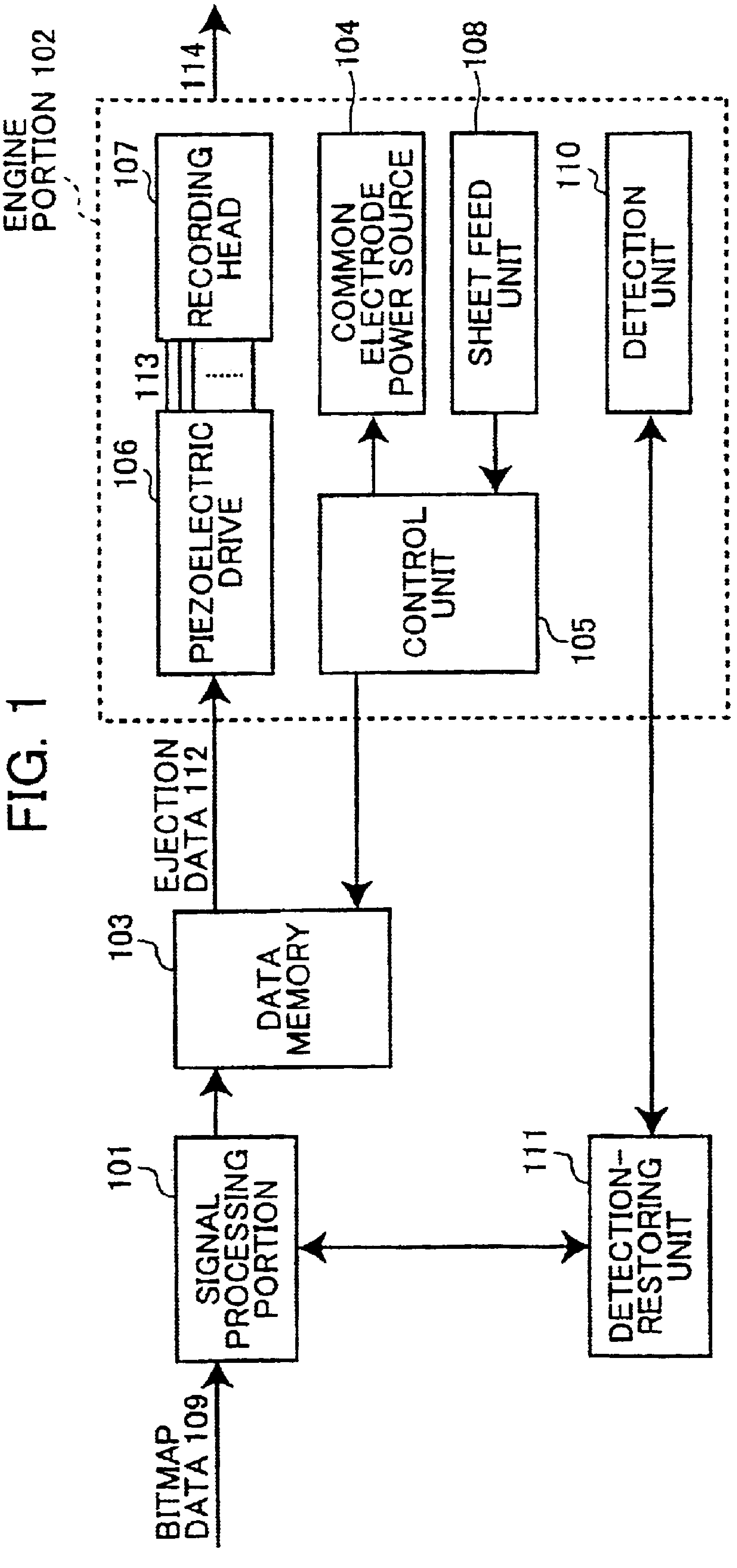

ENGINE PORTION 102
114
104
108
107
RECORDING HEAD
COMMON ELECTRODE POWER SOURCE
SHEET FEED UNIT
110
DETECTION UNIT
113
106
PIEZOELECTRIC DRIVE
CONTROL UNIT
105
EJECTION DATA 112
103
DATA MEMORY
101
SIGNAL PROCESSING PORTION
111
DETECTION-RESTORING UNIT
BITMAP DATA 109

FIG. 2

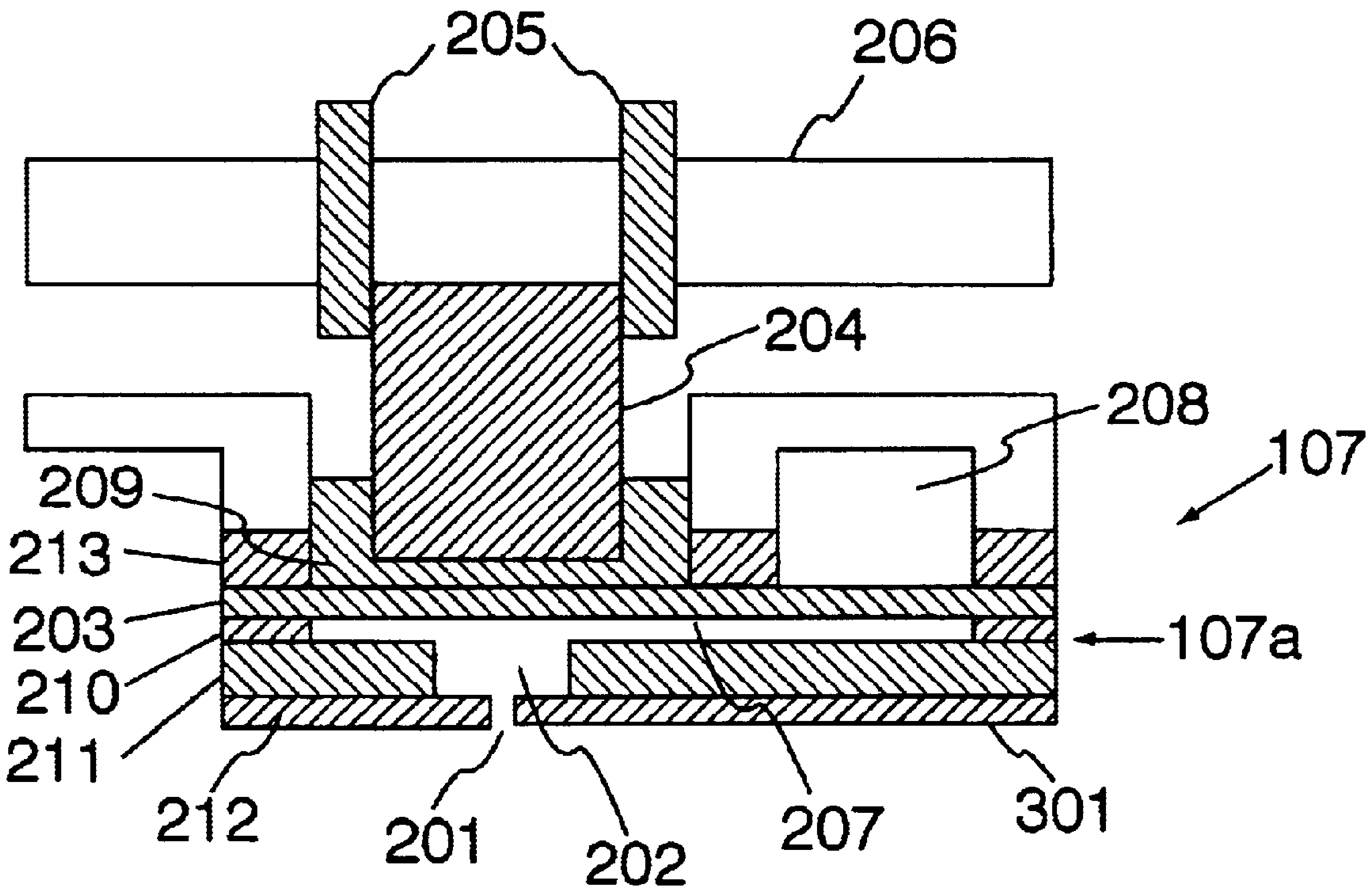


FIG.3(a)

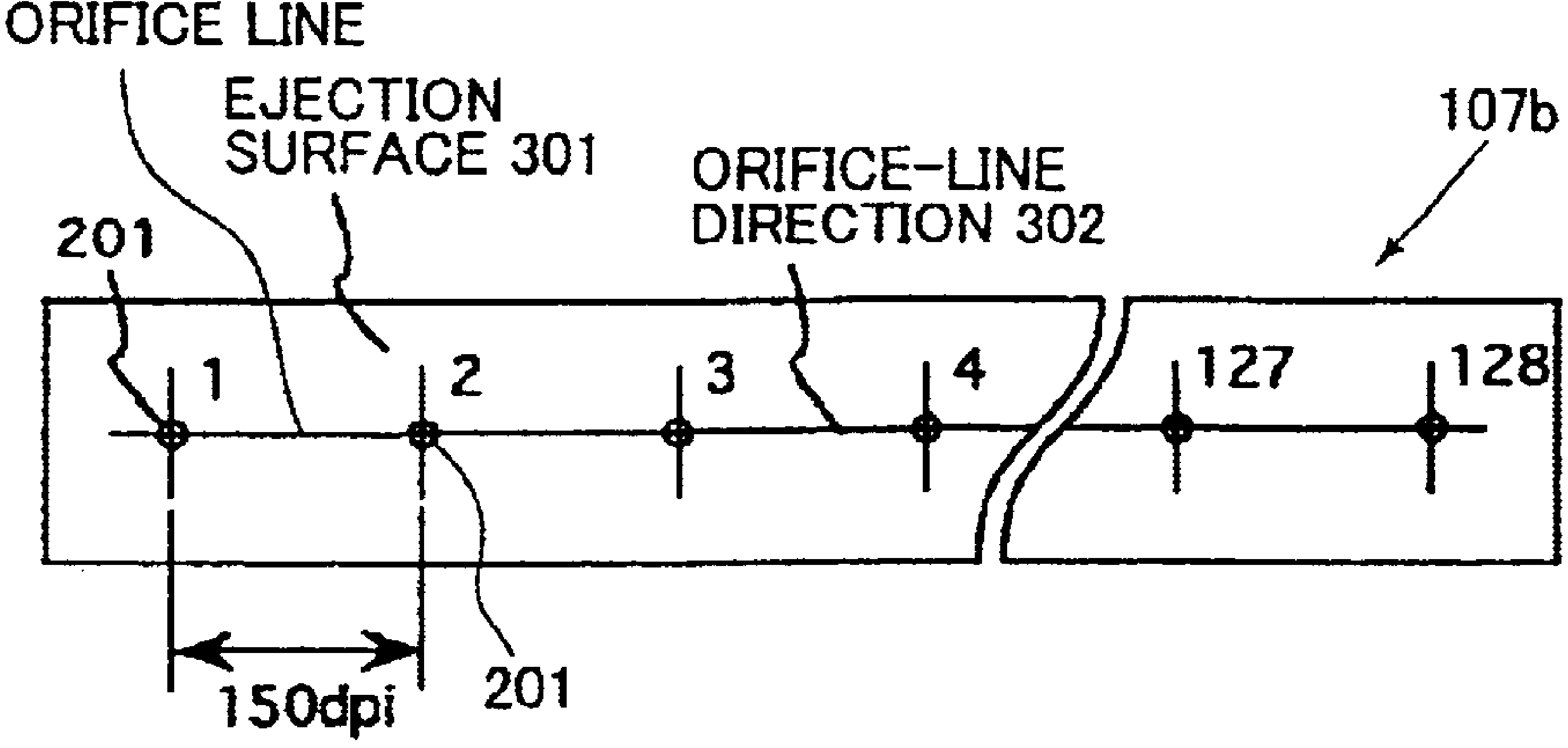


FIG.3(b)

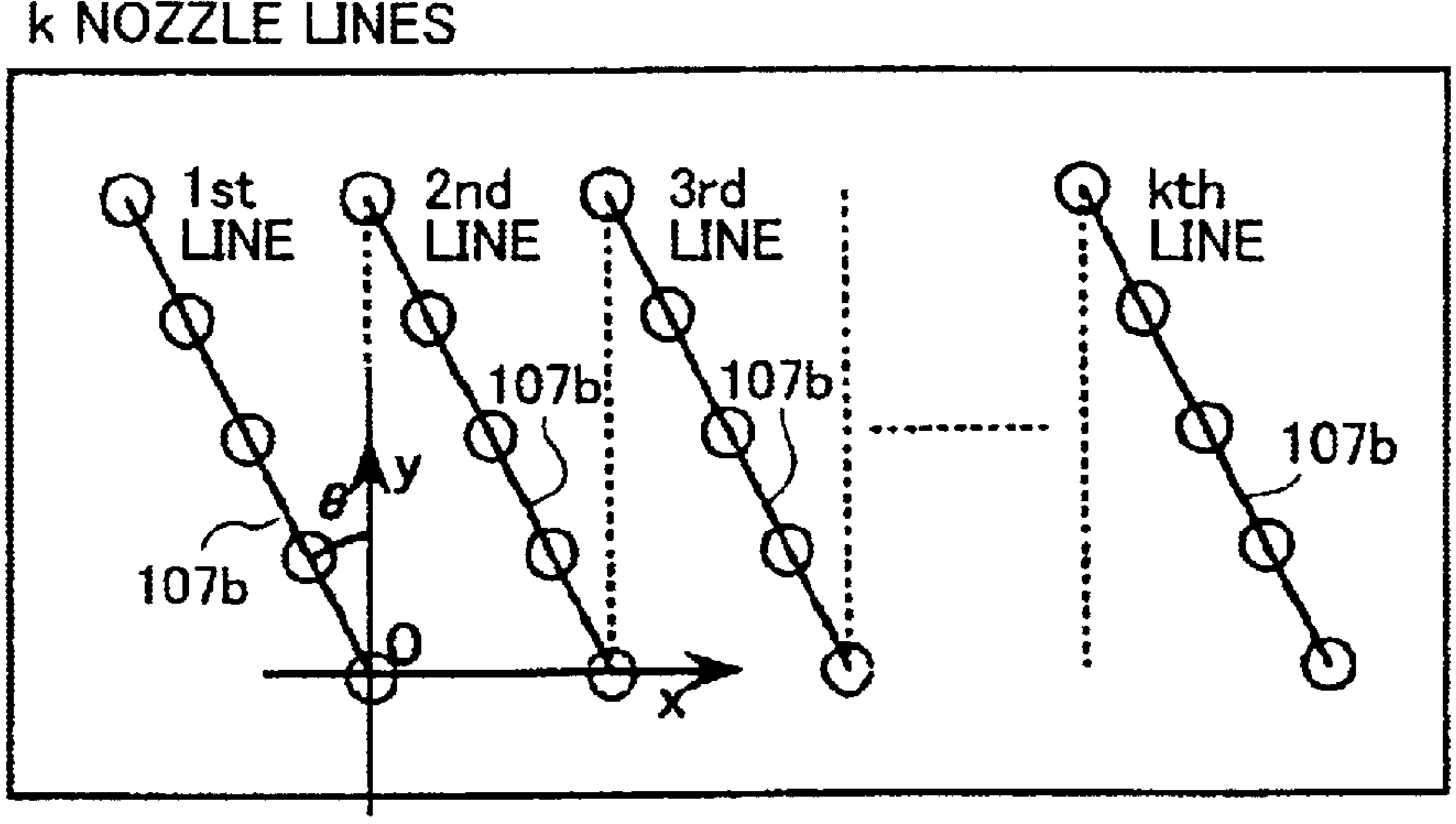


FIG.4

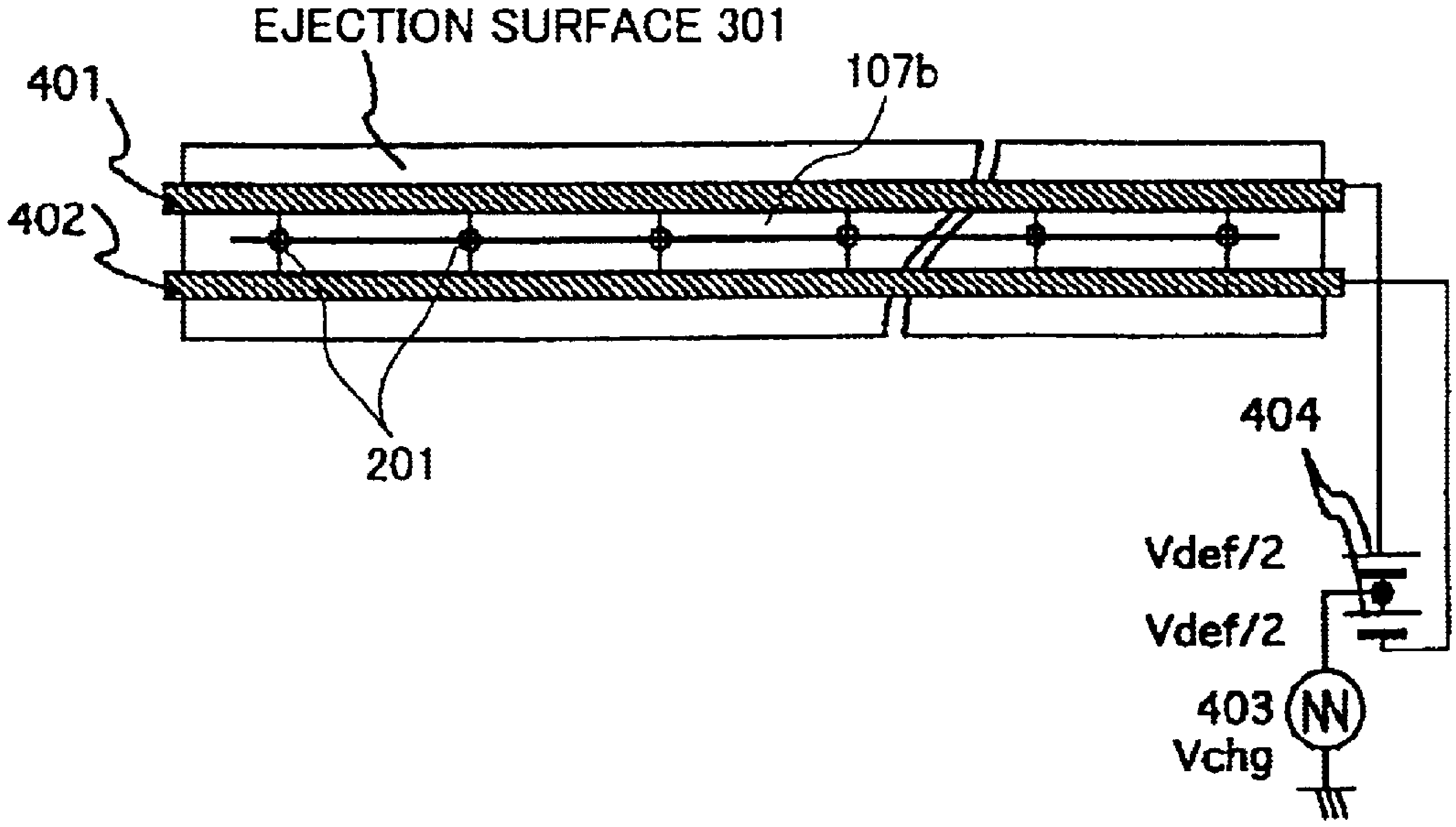


FIG. 5

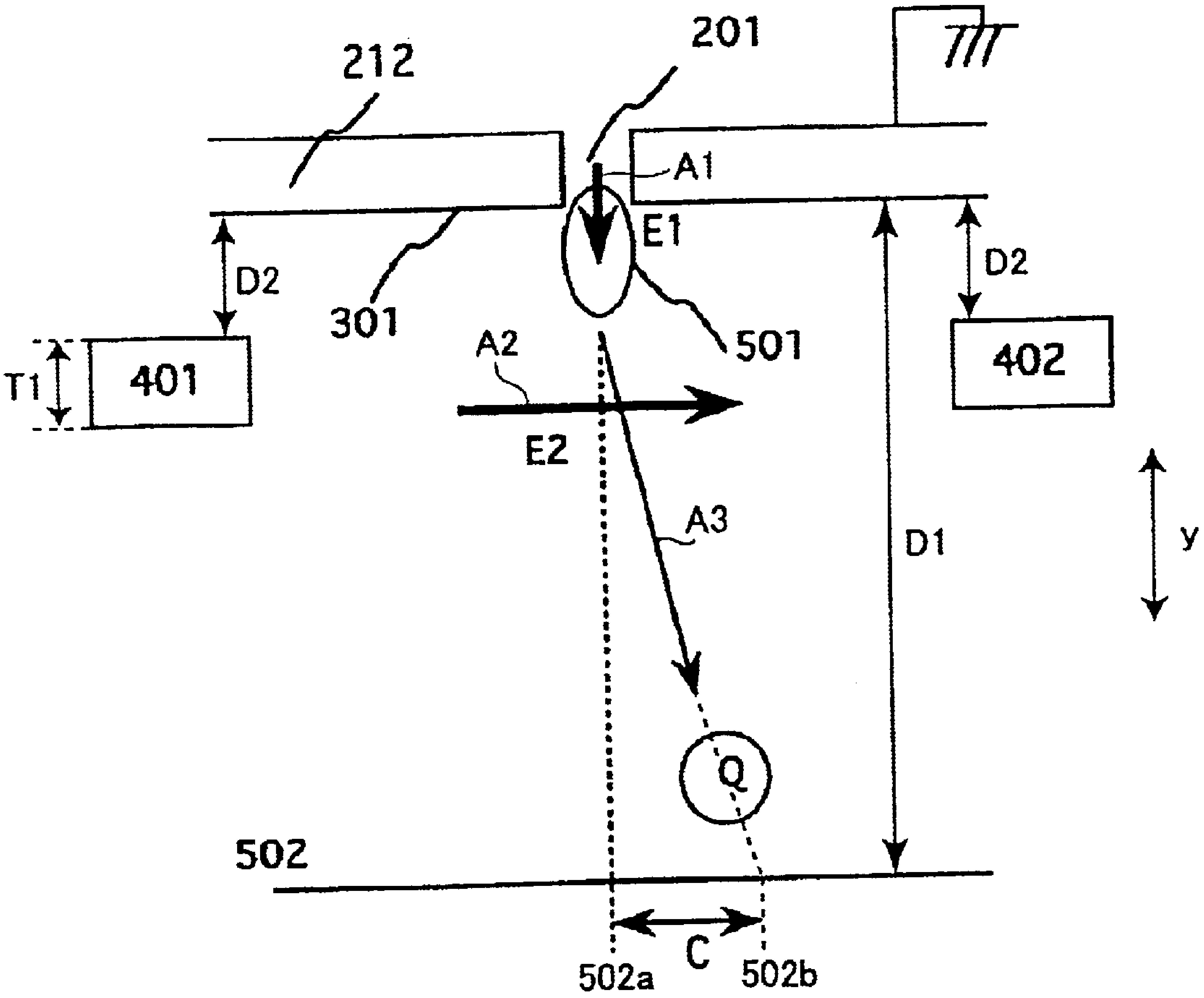


FIG. 6

ELECTRIC VOLTAGE Vchg (V)	DEFLECTION AMOUNT c (μm)	AVERAGE SPEED Vav (m/sec)
200	187	2.45
100	94	2.49
0	0	2.46
-100	-94	2.38
-200	-187	2.42

FIG. 7

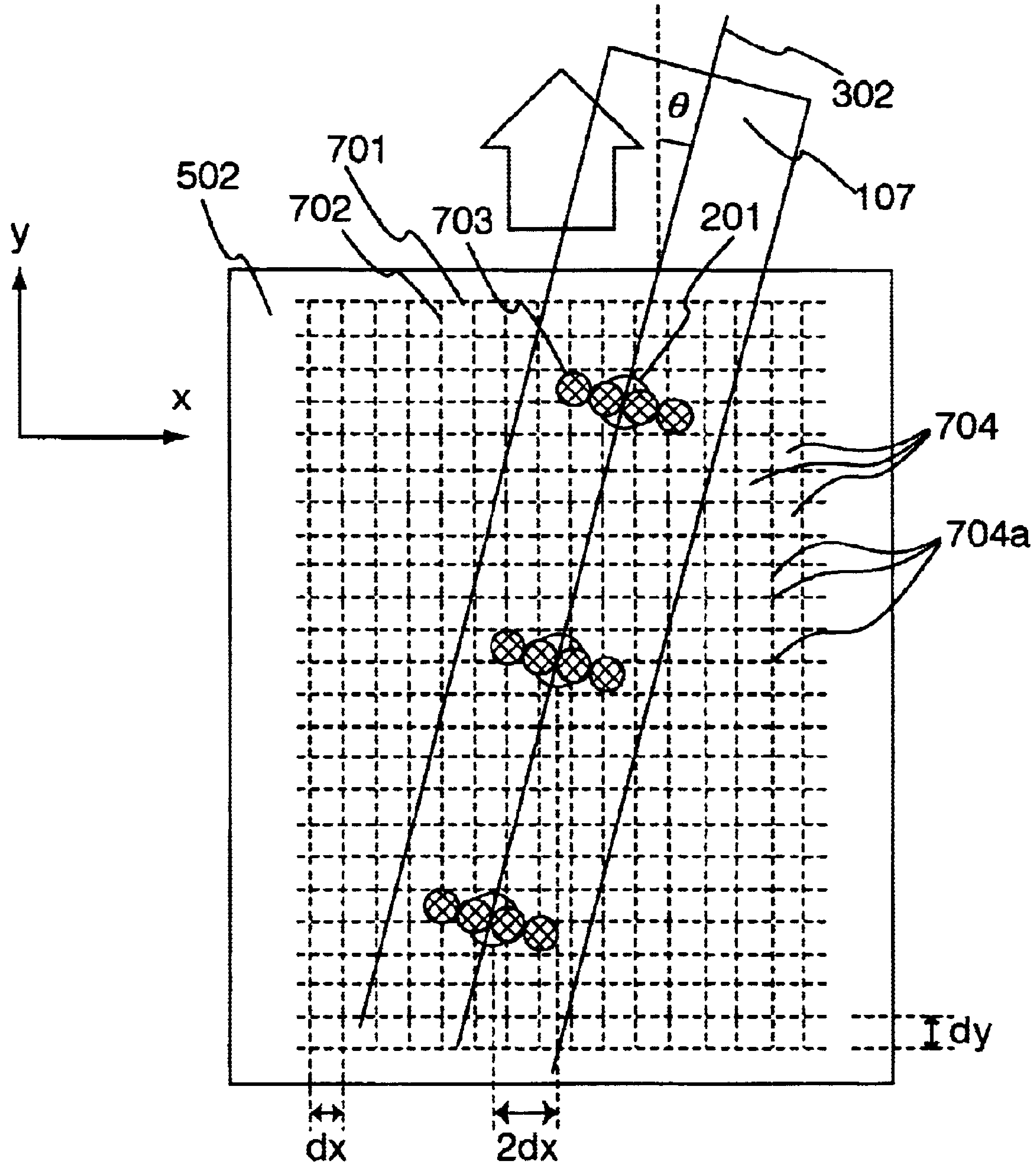


FIG.8(a)

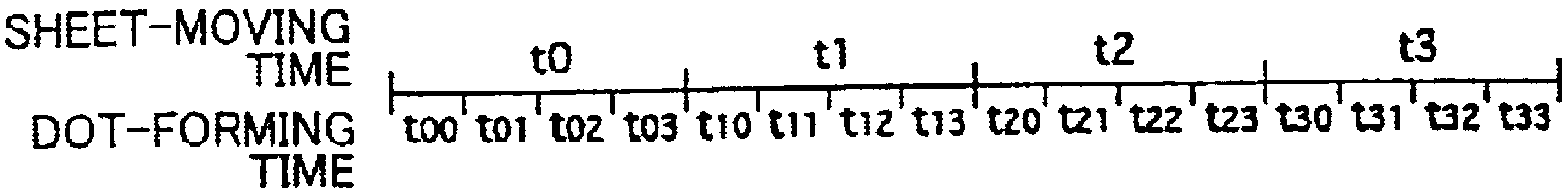


FIG.8(b)

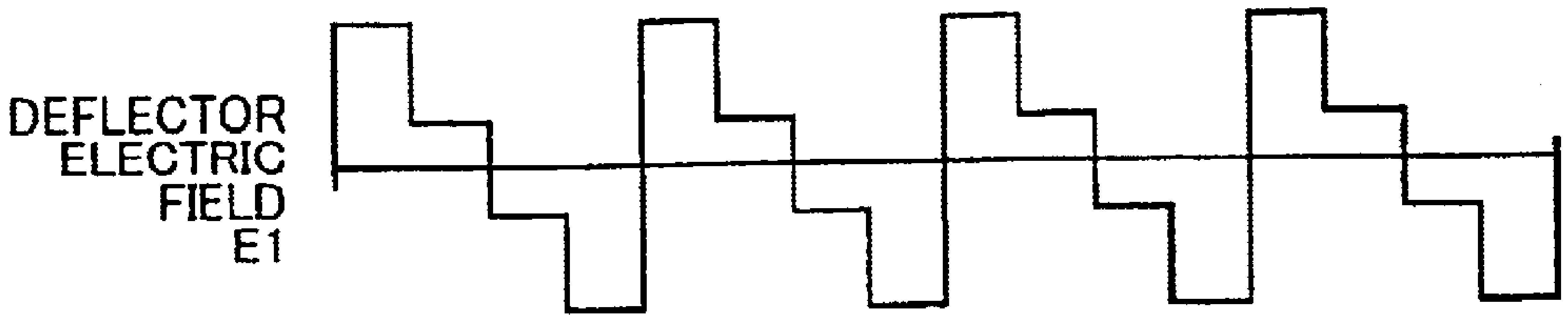


FIG.8(c)

EJECTION DATA 112	x	3	2	1	0	3	2	1	0	3	2	1	0	3	2	1	0
	y	0	0	0	0	1	1	1	1	2	2	2	2	3	3	3	3

FIG.8(d)

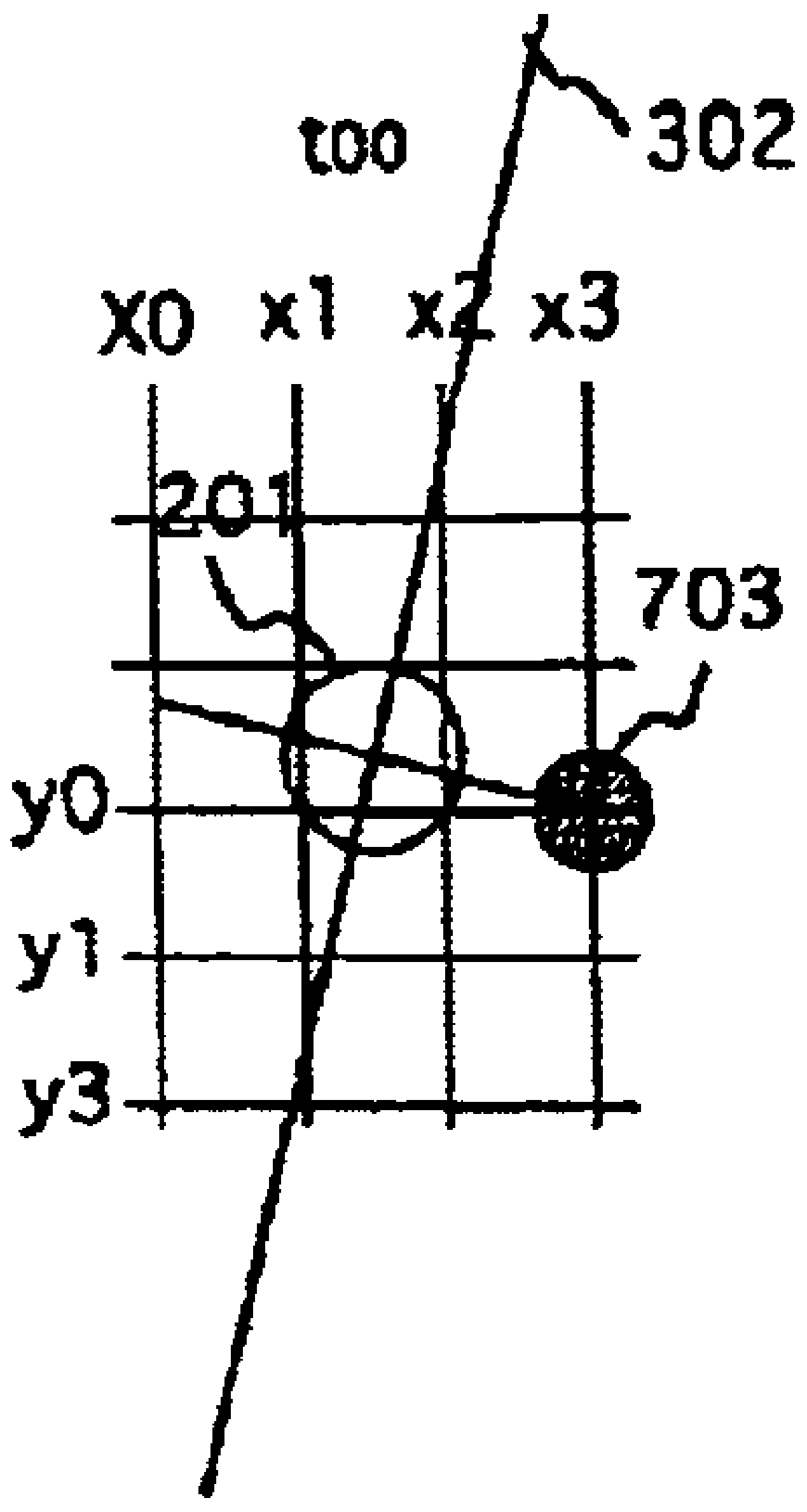


FIG.8(e)

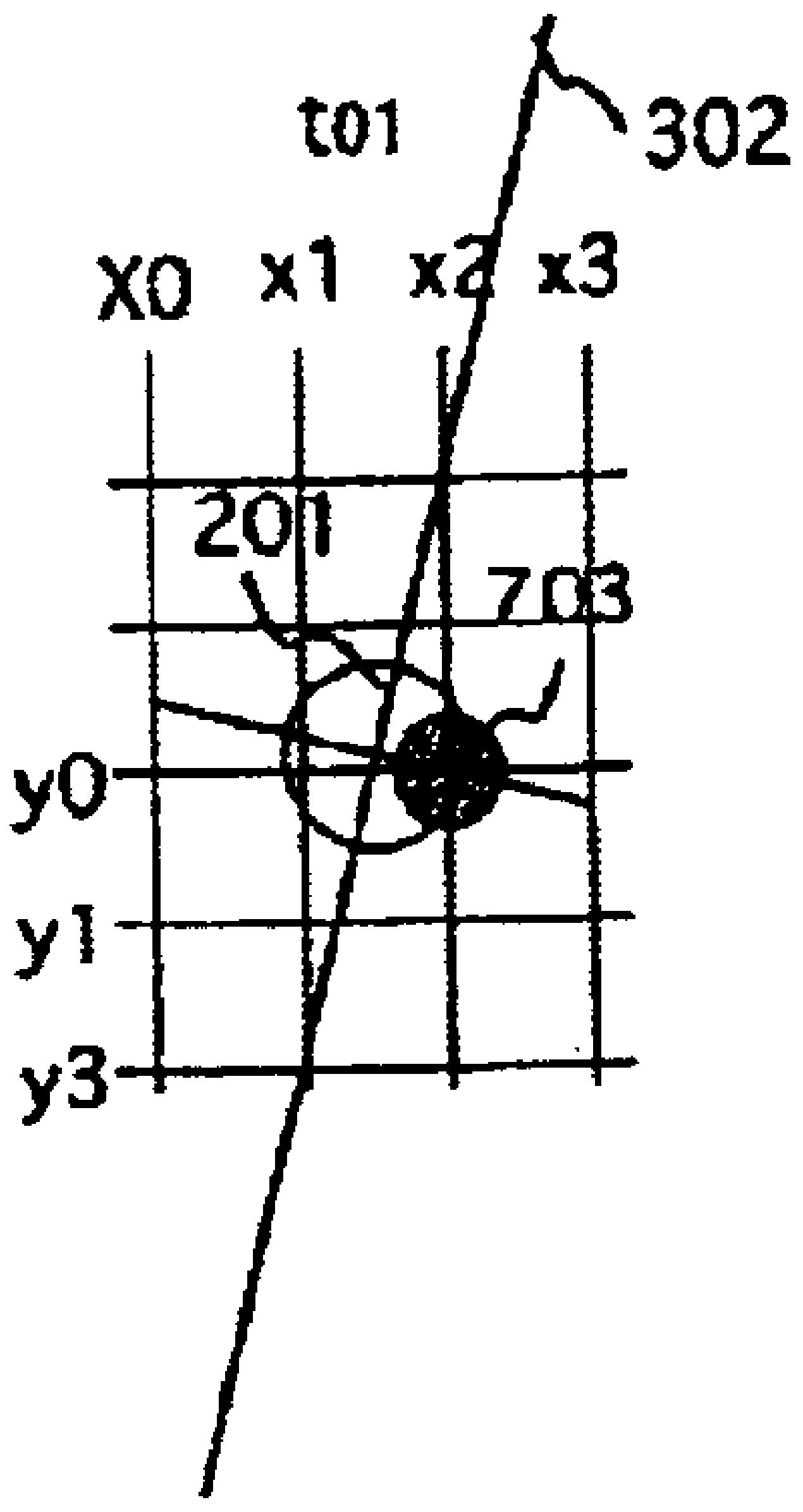


FIG.8(f)

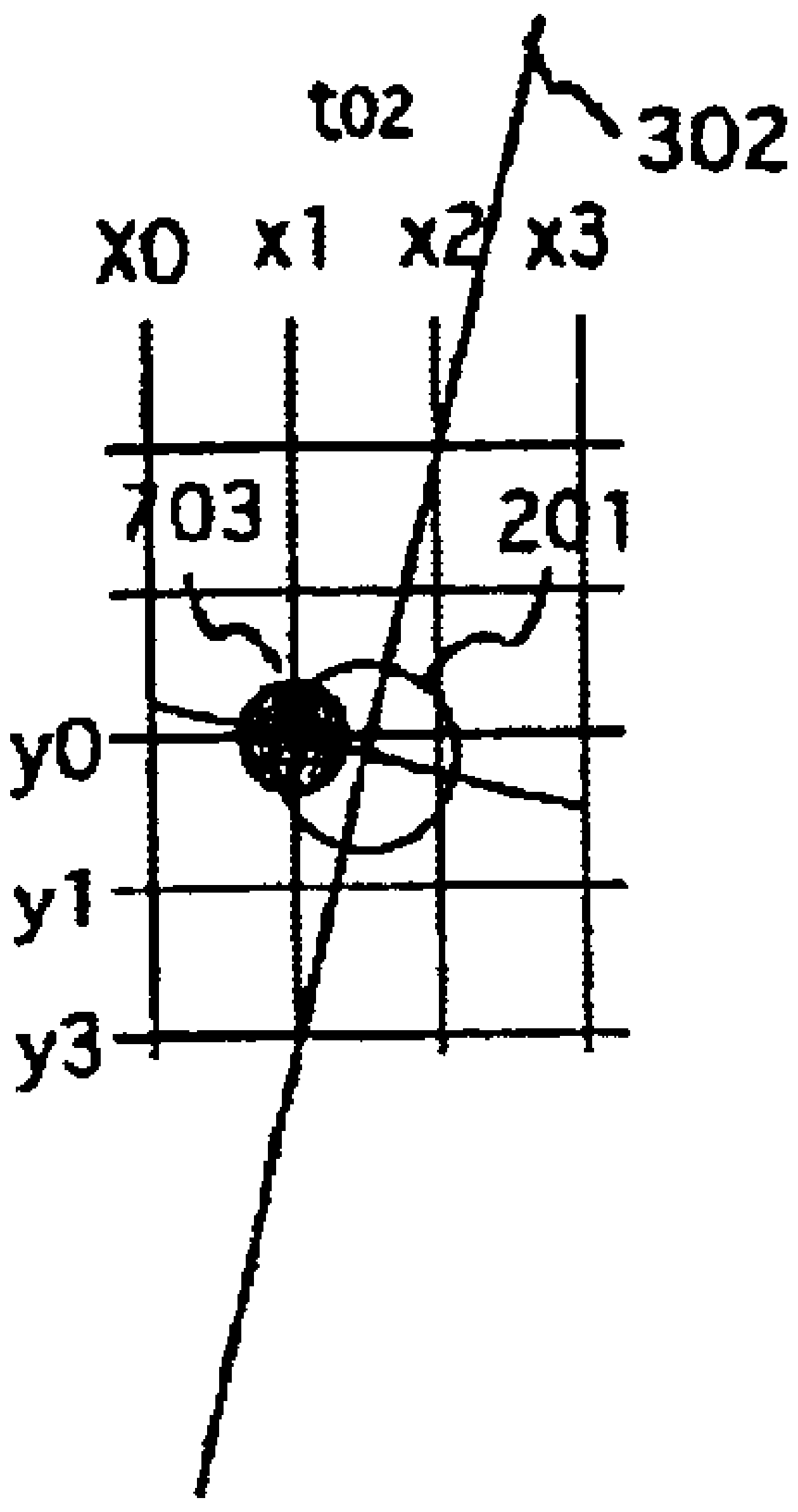


FIG.8(g)

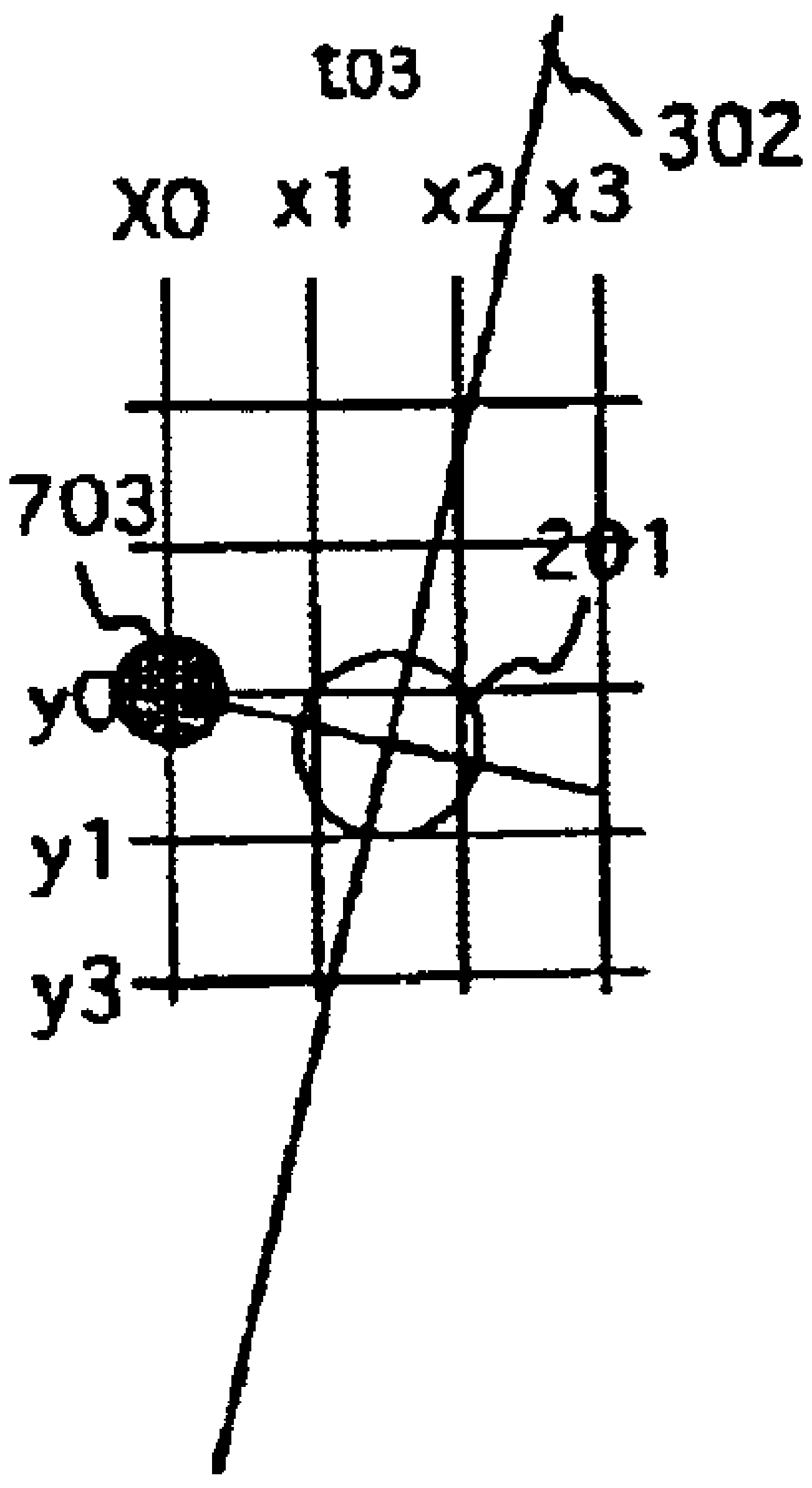


FIG. 9

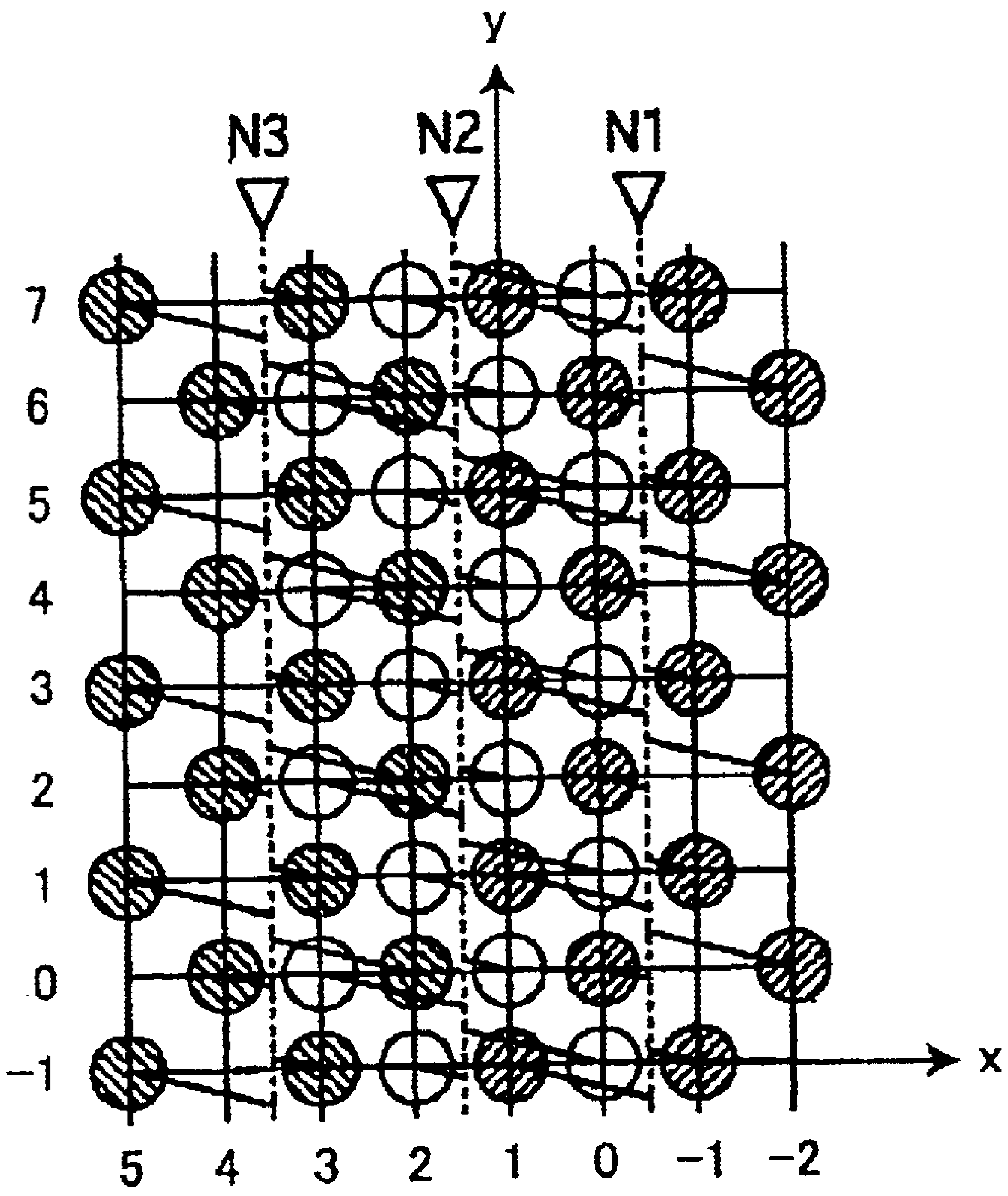


FIG. 10

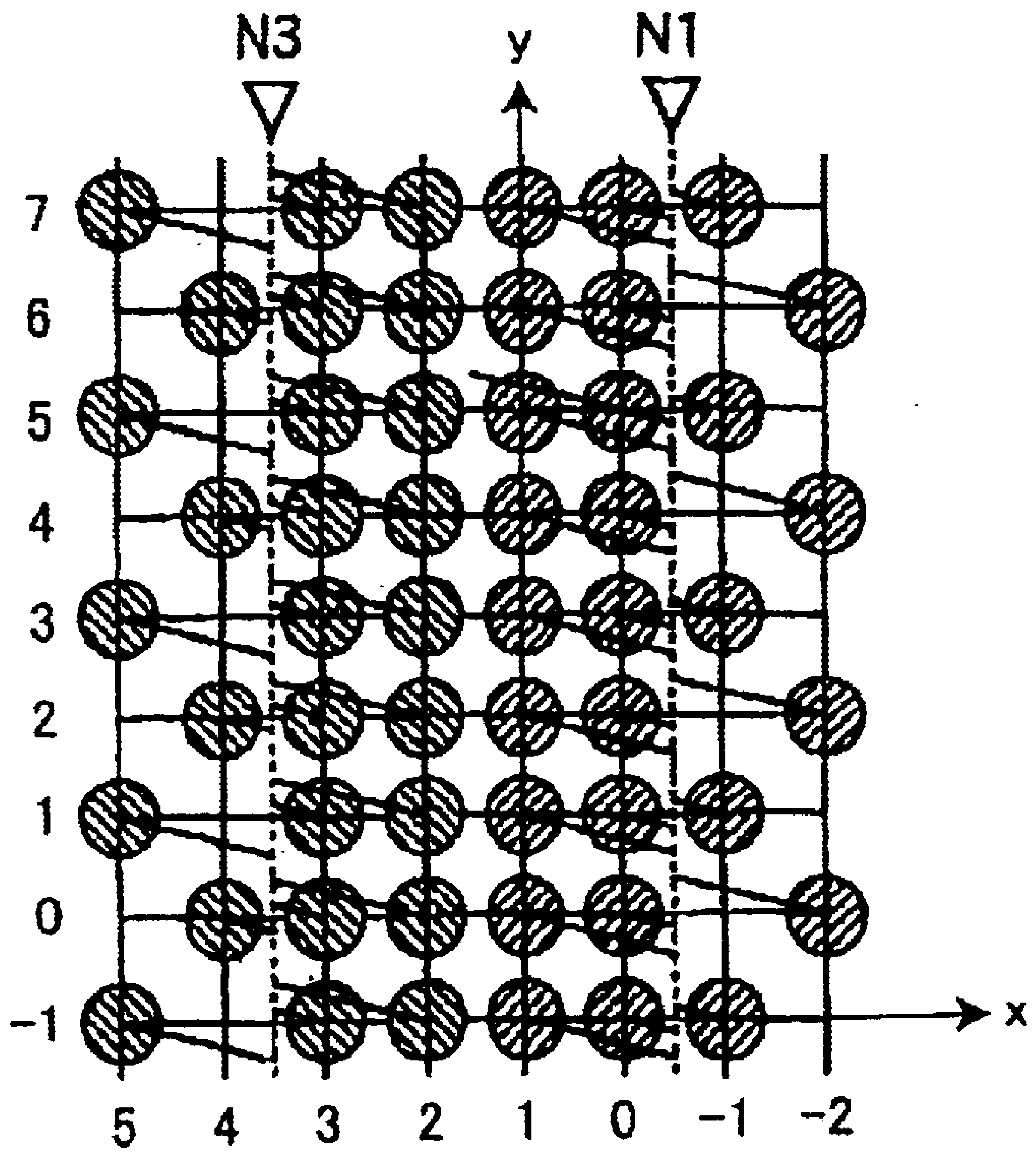


FIG. 11

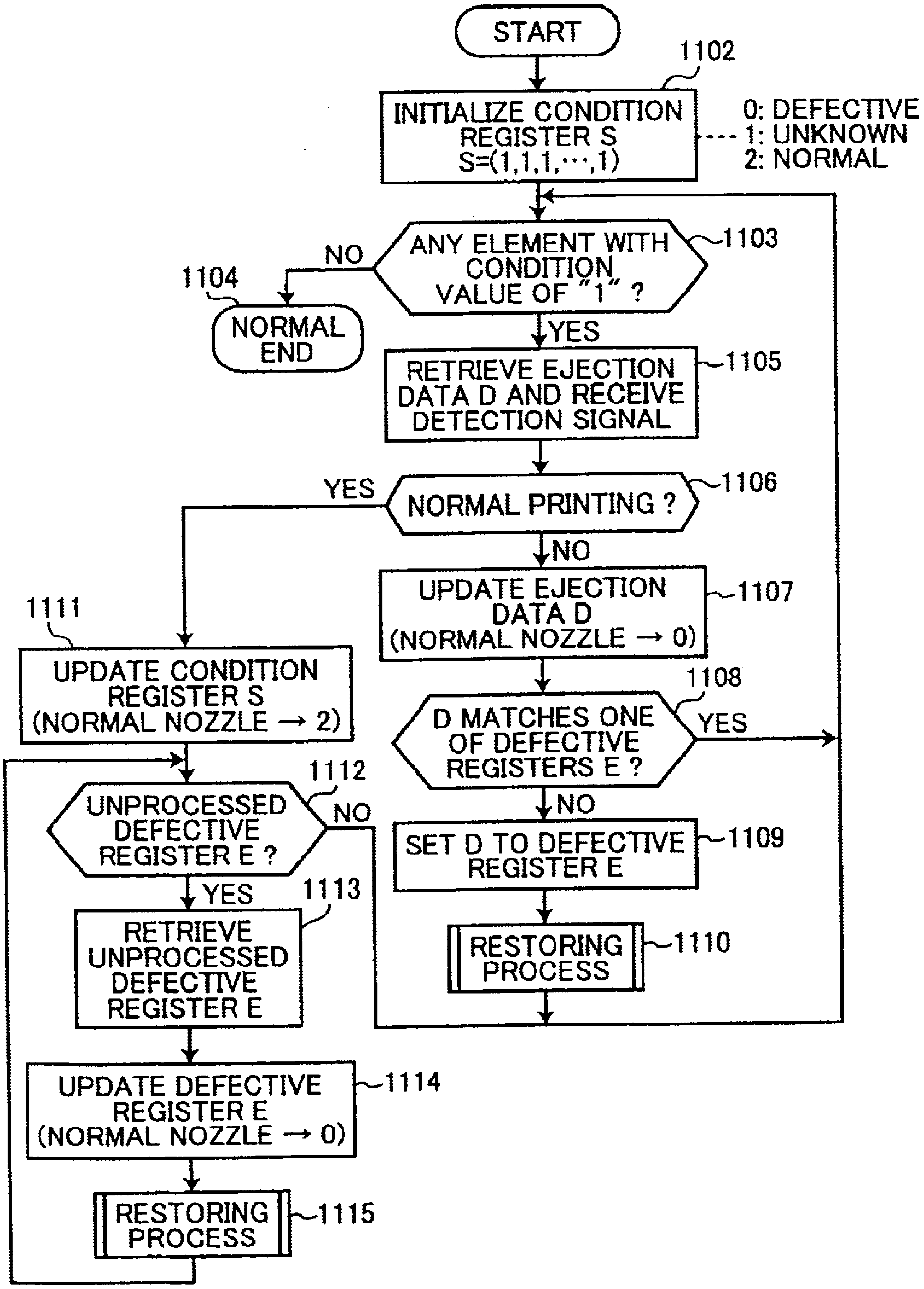

START
1102
INITIALIZE CONDITION REGISTER S S=(1,1,1,···,1)
0: DEFECTIVE
1: UNKNOWN
2: NORMAL
ANY ELEMENT WITH CONDITION VALUE OF "1" ?
1103
NO
1104
NORMAL END
YES
RETRIEVE EJECTION DATA D AND RECEIVE DETECTION SIGNAL
1105
NORMAL PRINTING ?
1106
YES
NO
UPDATE EJECTION DATA D (NORMAL NOZZLE → 0)
1107
D MATCHES ONE OF DEFECTIVE REGISTERS E ?
1108
YES
NO
SET D TO DEFECTIVE REGISTER E
1109
RESTORING PROCESS
1110
1111
UPDATE CONDITION REGISTER S (NORMAL NOZZLE → 2)
UNPROCESSED DEFECTIVE REGISTER E ?
1112
NO
YES
1113
RETRIEVE UNPROCESSED DEFECTIVE REGISTER E
UPDATE DEFECTIVE REGISTER E (NORMAL NOZZLE → 0)
1114
RESTORING PROCESS
1115

FIG. 12

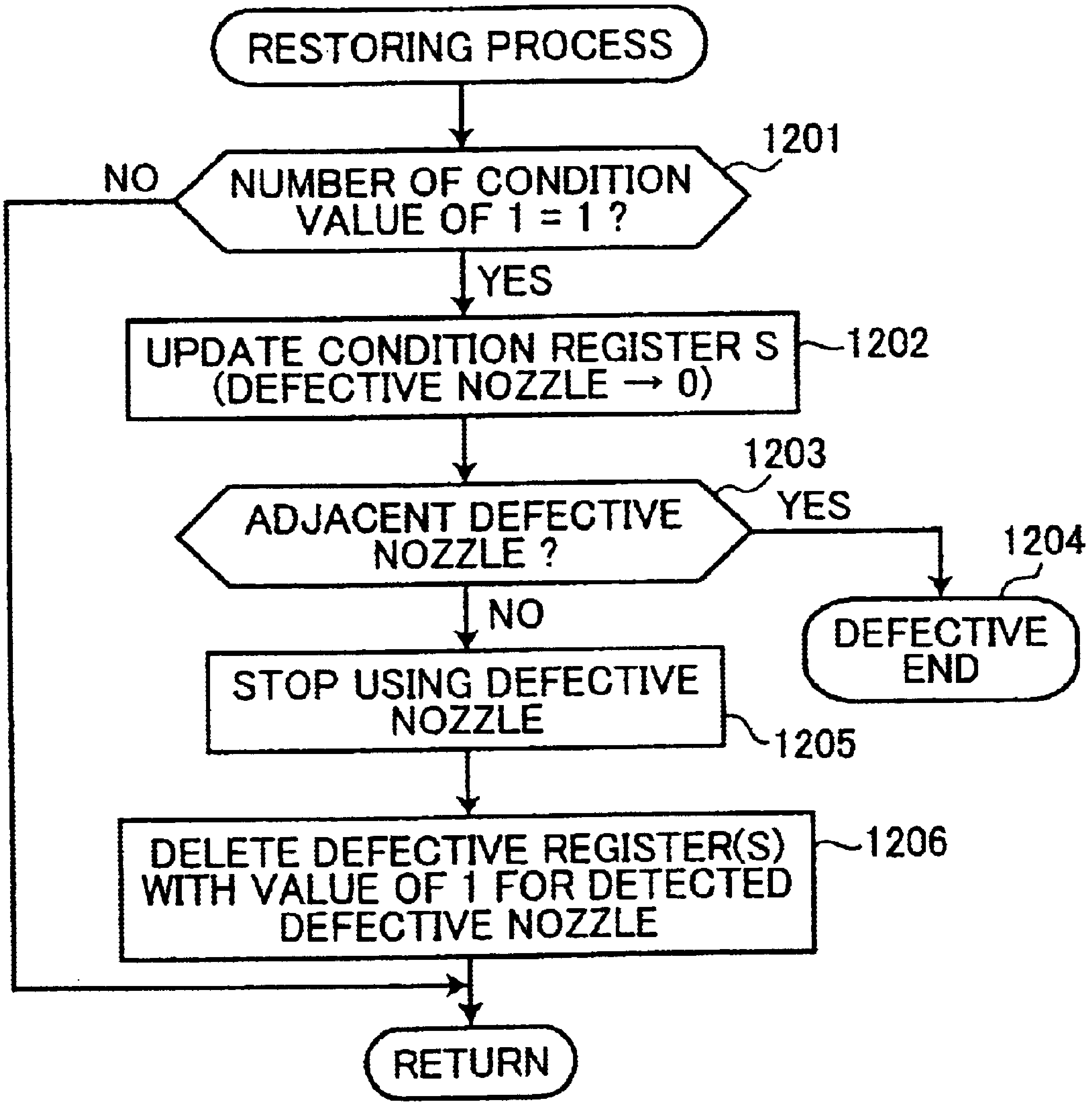

RESTORING PROCESS
1201
NUMBER OF CONDITION VALUE OF 1 = 1 ?
NO
YES
UPDATE CONDITION REGISTER S (DEFECTIVE NOZZLE → 0)
1202
1203
ADJACENT DEFECTIVE NOZZLE ?
YES
1204
DEFECTIVE END
NO
STOP USING DEFECTIVE NOZZLE
1205
DELETE DEFECTIVE REGISTER(S) WITH VALUE OF 1 FOR DETECTED DEFECTIVE NOZZLE
1206
RETURN

FIG. 13

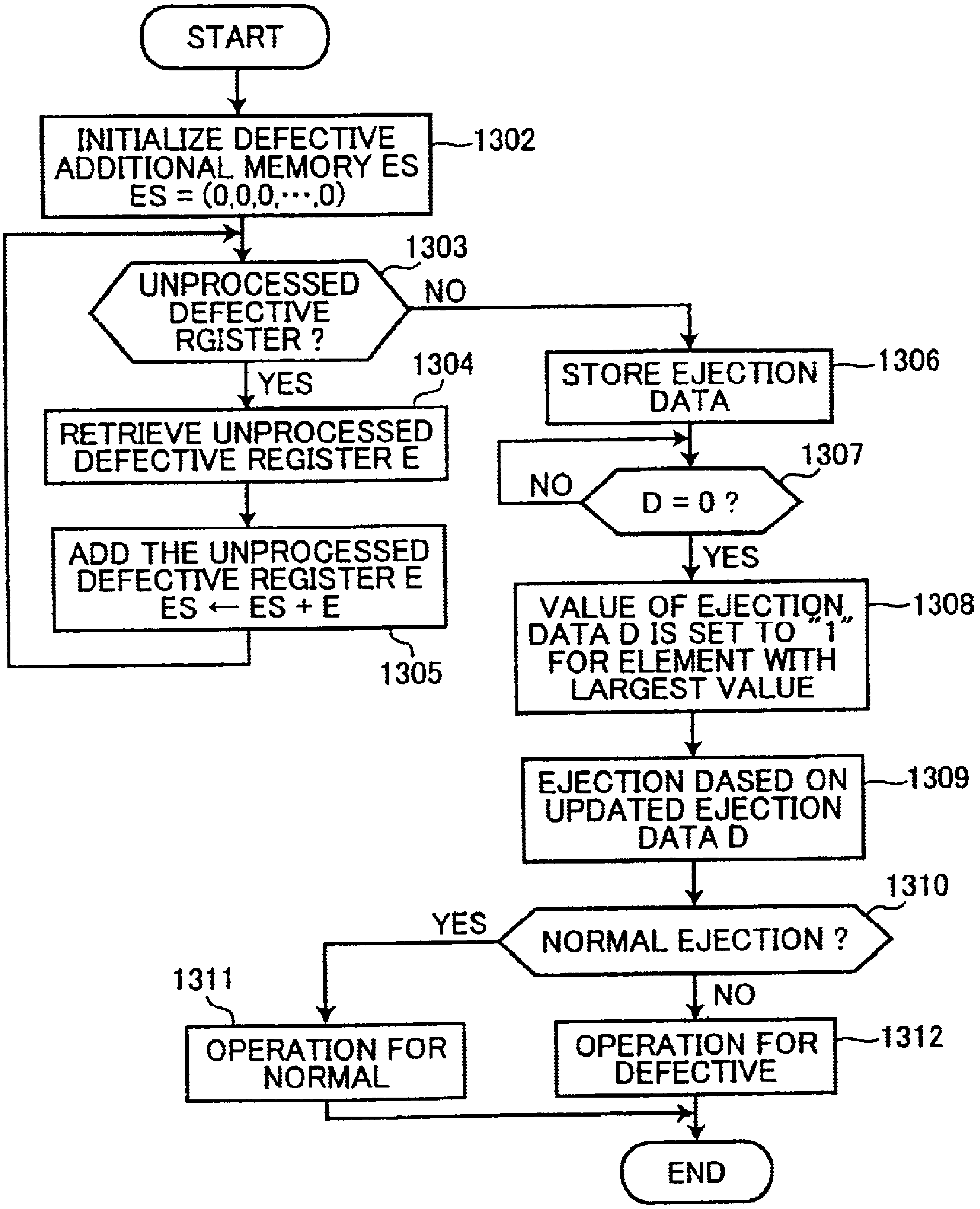

START
INITIALIZE DEFECTIVE ADDITIONAL MEMORY ES ES = (0,0,0,⋯,0)
1302
1303
UNPROCESSED DEFECTIVE RGISTER ?
NO
YES
1304
RETRIEVE UNPROCESSED DEFECTIVE REGISTER E
ADD THE UNPROCESSED DEFECTIVE REGISTER E ES ← ES + E
1305
STORE EJECTION DATA
1306
1307
NO
D = 0 ?
YES
VALUE OF EJECTION DATA D IS SET TO "1" FOR ELEMENT WITH LARGEST VALUE
1308
EJECTION DASED ON UPDATED EJECTION DATA D
1309
1310
YES
NORMAL EJECTION ?
NO
1311
OPERATION FOR NORMAL
OPERATION FOR DEFECTIVE
1312
END

FIG. 14

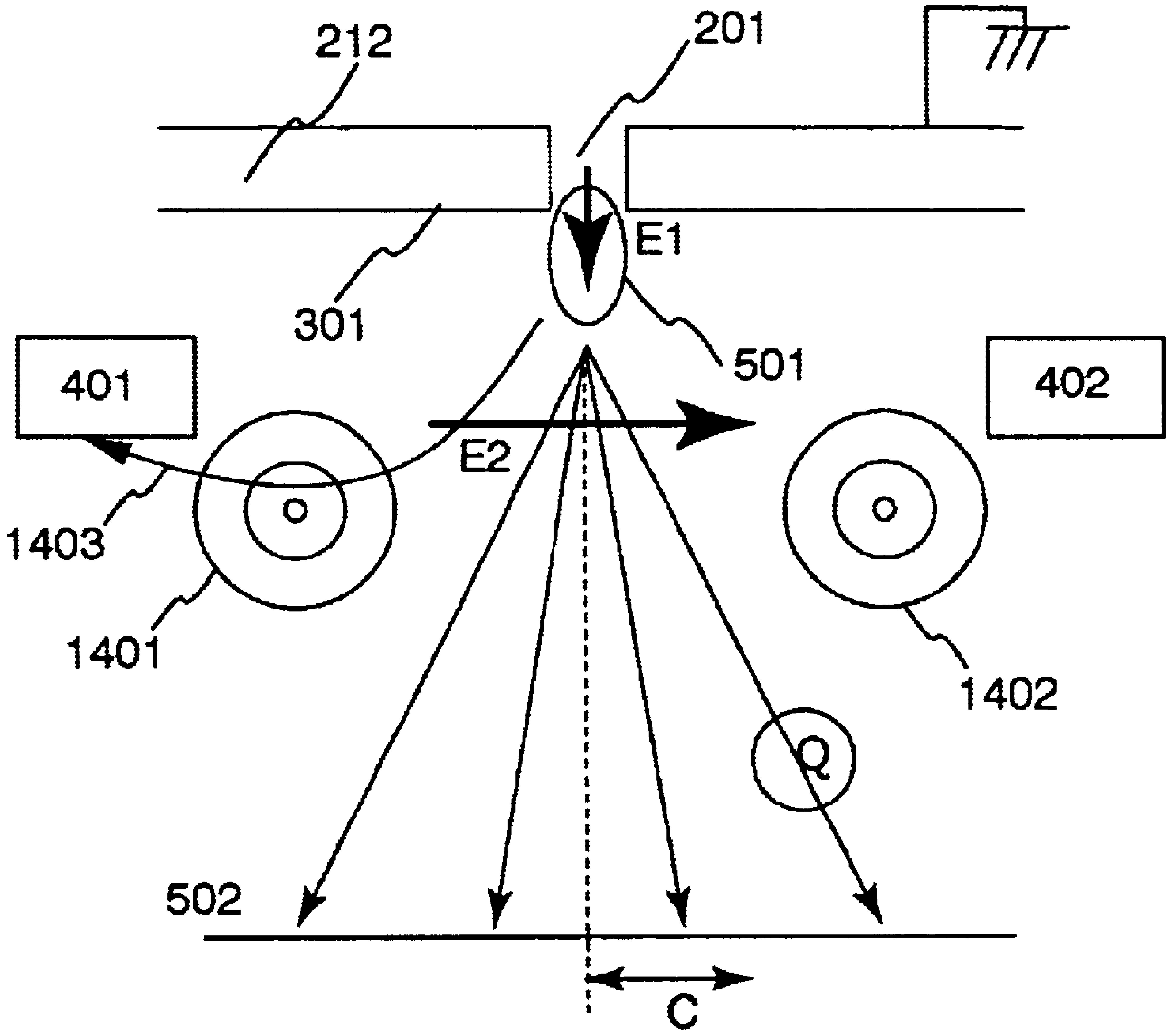
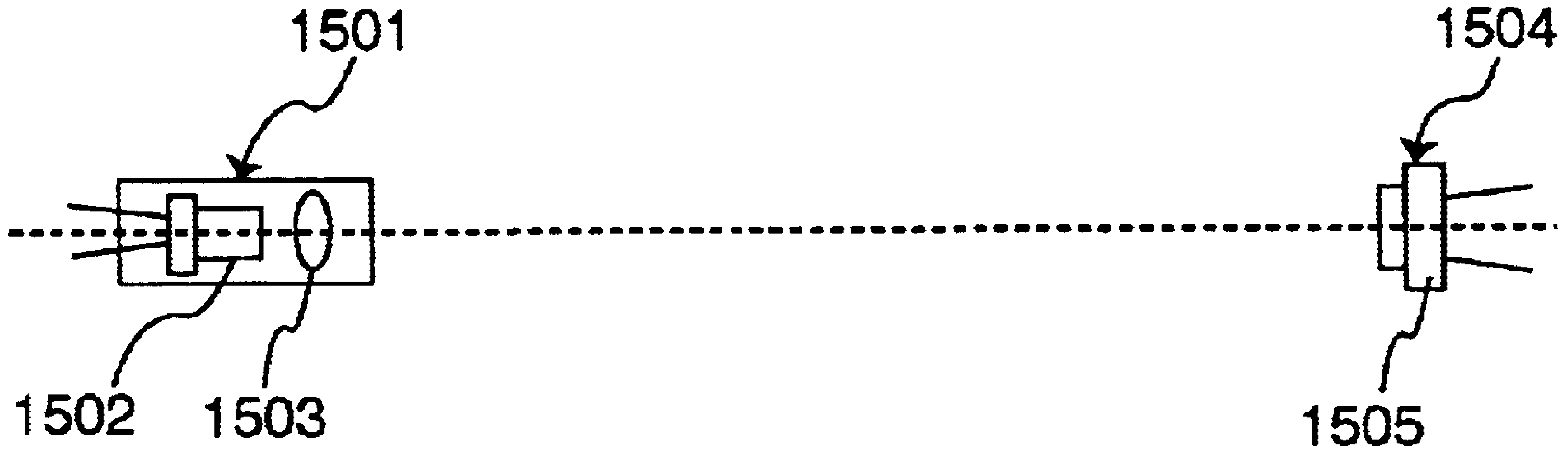

212
201
E1
301
501
401
402
E2
1403
1401
1402
Q
502
C

FIG. 15


1501
1504
1502
1503
1505

MULTINOZZLE INK JET RECORDING DEVICE CAPABLE OF IDENTIFYING DEFECTIVE NOZZLE

BACKGROUND OF THE INVENTION

1. Field of the Invention

The present invention relates to a multi-nozzle ink jet recording device, and more specifically to a highly reliable multi-nozzle ink jet recording device capable of automatically detecting defective nozzles and restoring normal printing without performing a test-pattern printing.

2. Related Art

Japanese Patent Publication No. SHO-47-7847 discloses a conventional ink jet recording device formed with a plurality of nozzles aligned in a line in a widthwise direction of a recording sheet. Ink droplets ejected from the nozzles impact and form dots on the recording sheet while the recording sheet is moved in a sheet feed direction perpendicular to the widthwise direction, thereby forming dot images on the recording sheet. The ejected ink droplets are uniform in their size and separated one from the other.

The recording device also includes electrodes that generate a charging electric field and a deflector electric field for respective nozzles. The charging electric field charges the ejected ink droplets based on a recording signal, and the deflector electric field having a uniform magnitude changes a flying direction of the charged ink droplets as needed, thereby controlling the impact positions of the ink droplets with respect to the widthwise directions so as to form the dots on exact target positions.

There has been also proposed a nozzle array where a plurality of nozzles are formed in an arrayed manner, which improves recording speed. However, increase in the number of nozzles sacrifices the reliability of the device.

Air bubbles and any foreign substances existing within a nozzle will result in ink droplets ejected at an angle and also in a splash where unintended minute ink droplets are generated. In worse case, no ejection is performed.

Moreover, when the ejection direction is angled or when the splash is caused in this manner, ink droplets may impact and cling on the electrodes. Especially, the splashed minute ink droplets have a low flying speed and a greater deflection amount because of their small diameter, so a large number of minute ink droplets cling on the electrodes. Because the ink has been charged by the charging electric field, the ink clinging on the electrodes increases an electric current conducting through the electrodes. Therefore, a nozzle corresponding to the electrodes with increased electric current can be easily detected defective.

However, the above method for detecting defective nozzles is not useful in a recording device including common electrodes used common to a plurality of nozzles. Specifically, when there is any change in electric current, it can be known that there is a defective nozzle(s). However, because the amount of change in the electric current due to a single defective nozzle is unknown and fluctuates, it is impossible to detect the number of defective nozzle(s) or to identify the defective nozzle(s). For example, even if defective ejection is detected when droplets are ejected from two nozzles at one time, it cannot detect which one of the two nozzles is defective or whether both of the two nozzles are defective.

It is conceivable to perform a test-pattern printing where an ink droplet is ejected from each one of the nozzles one at a time. Then, it is determined whether or not each nozzle is defective or normal by using a laser beam or a CCD sensor. However, this method is time consuming and wastes ink, and it is impossible to perform such a time-consuming test-pattern printing during actual image forming operations. Moreover, there is hardly a case when an ink droplet is ejected from only a single nozzle during the actual printing, not the test-pattern printing, so it is unrealistic to wait such a single-nozzle printing during the actual printing to detect defectiveness of each nozzle. That is, even when a nozzle becomes defective during printing, there has been no conventional means for restoring the normal printing during the printing, so that there has been no choice but to continue the defective printing with the defective nozzle.

There is a choice to temporarily stop the printing to detect a defective nozzle. However, this method wastes time required for the detection, wastes ink contributed for the detection, and requires disposing the ink contributed for the detection. Accordingly, it is preferable to avoid such an operation as much as possible.

SUMMARY OF THE INVENTION

It is therefore an objective of the present invention to overcome the above problems, and also to provide a highly reliable multi-nozzle ink jet recording device capable of automatically detecting defective nozzles and restoring normal printing without performing a test-pattern printing.

In order to overcome the above and other objectives, there is provided an ink jet recording device including a head, electrodes, first detecting means, and identifying means. The head is formed with a plurality of nozzles through which ink droplets are selectively ejected based on ejection data during printing. The electrodes are provided common to the plurality of nozzles. The first detecting means detects whether all of selected nozzles through which ink droplets are ejected are normal or at least one of the selected nozzles is defective. The identifying means automatically identifies a defective nozzle while the head is continuously performing the printing when the first detecting means detects that the ejection is performed defective.

There is also provided a detecting method of detecting a defective nozzle among a plurality of nozzles formed to a head of an ink jet recording device that includes the head and electrodes for generating a deflection electric field common to the plurality of nozzles. The detecting method includes the steps of a) detecting whether all of selected nozzle through which ink droplets are ejected are normal or at least one of the selected nozzles is defective, and b) identifying a defective nozzle among the plurality of nozzles while the head continuously performing the printing when the ejection is detected defective in step a).

BRIEF DESCRIPTION OF THE DRAWINGS

In the drawings:

FIG. **1** is a block diagram of components of an ink jet recording device according to an embodiment of the present invention;

FIG. **2** is a cross-sectional view of a nozzle formed to a recording head of the ink jet recording device;

FIG. **3**(*a*) is a plan view partially showing an ejection surface of the recording head;

FIG. **3**(*b*) is a plan view showing the ejection surface of the recording head;

FIG. **4** is an explanatory plan view showing the ejection surface and common electrodes;

FIG. **5** is an explanatory cross-sectional view showing ink droplet deflection;

FIG. **6** is a table indicating deflection results;

FIG. **7** is an explanatory view showing a partial configuration of engine portion including the recording head **107**;

FIG. **8**(*a*) is an explanatory view showing a dot frequency and a deflected-dot frequency;

FIG. **8**(*b*) is an explanatory view showing change in magnitude of a deflector electric field;

FIG. **8**(*c*) is an explanatory view showing ejection data;

FIG. **8**(*d*) is an explanatory view showing a positional relationship between an orifice and an impact position of a deflected ink droplet;

FIG. **8**(*e*) is an explanatory view showing a positional relationship between an orifice and an impact position of a deflected ink droplet;

FIG. **8**(*f*) is an explanatory view showing a positional relationship between an orifice and an impact position of a deflected ink droplet;

FIG. **8**(*g*) is an explanatory view showing a positional relationship between an orifice and an impact position of a deflected ink droplet;

FIG. **9** is an explanatory view showing an example of ink ejection and deflection;

FIG. **10** is an explanatory view of adjusted ink ejection and deflection for when a nozzle N2 becomes defective;

FIG. **11** is a flowchart representing a detecting process according to a first embodiment of the present invention;

FIG. **12** is a flowchart representing a restoring process executed in S1110 and S1115 of FIG. **11**;

FIG. **13** is a flowchart representing a detecting process according to a second embodiment of the present invention;

FIG. **14** is a cross-sectional view showing a configuration of an ink jet head according to a third embodiment of the present invention; and

FIG. **15** is a plan view sowing a laser beam generator and a laser beam receptor according to the third embodiment of the present invention.

PREFERRED EMBODIMENTS OF THE PRESENT INVENTION

Next, a line-scanning-type multi-nozzle ink jet recording device and a recording method according to an embodiment of the present invention will be described while referring to the accompanying drawings.

First, overall configuration of the line-scanning-type multi-nozzle ink jet recording device **1** will be described while referring to FIGS. **1** to **8**.

As shown in FIG. **1**, the ink jet recording device **1** includes a signal processing portion **101**, a data memory **103**, an engine portion **102**, and a detection-restoring unit **111**. The engine portion **102** includes a control unit **105**, a piezoelectric driver **106**, a recording head **107**, a common electrode power source **104**, a sheet feed unit **108**, and a detection unit **110**. The recording head **107** is formed with a plurality of nozzles **107***a* (FIG. **2**). Because the piezoelectric driver **106** has a well-known configuration, detailed description thereof will be omitted.

When the ink jet recording device **1** is a full-color recording device, a plurality of recording heads **107** are provided for a plurality of different colored ink. However, in the present embodiment, it is assumed that the ink jet recording device **1** is a monochromatic recording device, and that only one recording head **107** is provided.

The signal processing portion **101** is a well-known microcomputer, and receives a bitmap data **109**, which is binary data, from an external computer and the like (not shown). When the ink jet recording device **1** is the full-color recording device, a plurality of sets of the bitmap data **109** are usually provided for the recording heads **107**.

Upon receipt of the bitmap data **109**, the signal processing portion **101** generates ejection data **112** for each of the nozzles **107***a* of the recording head **107** based on the bitmap data **109** and a prestored program. The ejection data **112** is arranged, based on position information of each nozzle **107***a* and deflection information of ink droplets, in an order in which ink droplets are ejected. The signal processing portion **101** temporarily stores one-scanning-worth or one-page-worth of the ejection data **112** into the data memory **103**.

The control unit **105** of the engine portion **102** controls the sheet feed unit **108** and the common electrode power source **104**. When printing is started, the sheet feed unit **108** starts feeding a recording sheet. At the same time, the common electrode power source **104** applies an electric voltage to common electrodes **401**, **402** (FIGS. **4** and **5**) to be described later, thereby generating a charging electric field and a deflector electric field. When a recording position of the recording sheet reaches the recording head **107**, the control unit **105** outputs a request command to the data memory **103**, the request command requesting the signal data memory **103** to output the ejection data **112**. The ejection data **112** is input to the piezoelectric driver **106**, and the piezoelectric driver **106** outputs a print signal **113** to each nozzle **107***a* of the recording head **107**. As a result, an image **114** is formed on the recording sheet.

In the ink jet recording device **1** of the present embodiment, printing is performed by the recording head **107** that is held still while the recording sheet is transported.

As shown in FIG. **2**, each nozzle **107***a* of the recording head **107** includes a diaphragm **203**, a piezoelectric element **204**, a signal input terminal **205**, a piezoelectric element supporting substrate **206**, a restrictor plate **210**, a pressure-chamber plate **211**, an orifice plate **212**, and a supporting plate **213**. The diaphragm **203** and the piezoelectric element **204** are attached to each other by a resilient member **209**, such as a silicon adhesive. The restrictor plate **210** defines a restrictor **207**. The pressure-chamber plate **211** and the orifice plate **212** define a pressure chamber **202** and an orifice **201**, respectively. The orifice plate **212** has an ejection surface **301**. A common ink supply path **208** is formed above the pressure chamber **202** and is fluidly connected to the pressure chamber **202** via the restrictor **207**. Ink flows from above to below through the common ink supply channel **208**, the restrictor **207**, the pressure chamber **202**, and the orifice **201**. The restrictor **207** regulates an ink amount supplied into the pressure chamber **202**. The supporting plate **213** supports the diaphragm **203**. The piezoelectric element **204** deforms when a voltage is applied to the signal input terminal **205**, and maintains its initial shape when no voltage is applied.

The diaphragm **203**, the restrictor plate **210**, the pressure-chamber plate **211**, and the supporting plate **213** are formed from stainless steel, for example. The orifice plate **212** is formed from nickel material. The piezoelectric element supporting substrate **206** is formed from an insulating material, such as ceramics and polyimide.

The print signal **113** output from the piezoelectric driver **106** is input to the signal input terminal **205**. In accordance with the print signal **113**, uniform ink droplets separated from each other are ejected, ideally outwardly with respect to a normal line of the orifice plate **212**, from the orifice **201**.

As shown in FIG. **3**(*b*), a plurality of orifice lines **107***b* are formed to the recording head **107**. Details will be described below.

As shown in FIG. **3**(*b*), the ejection surface **301** is formed with a plurality of the orifice lines **107***b* arranged side by side in an x direction and each extending in an orifice-line direction **302**, which is inclined by θ with respect to a y direction perpendicular to the x direction. As shown in FIG. **3**(*a*), each orifice line **107***b* includes **128** orifices **201** arranged at a pitch of 75 orifices/inch in the orifice-line direction **302**. Although not indicated in the drawings, adjacent orifice lines **107***b* usually overlap each other in the x direction by several-dot-worth amount.

In actual assembly, a plurality of head portions of FIG. **3**(*a*) are assembled into the single head **107** of FIG. **3**(*b*). The above arrangement prevents unevenness in color density of recorded image, which appears in a black or white band, due to erroneous attachment of the head portions and uneven nozzle characteristics, and also enables assembly of the recording head **107** elongated in the x direction.

As shown in FIGS. **4** and **5**, the common electrodes **401**, **402** are provided for each orifice line **107***b*, at positions between the ejection surface **301** and a recording sheet **502**. The common electrodes **401**, **402** extend parallel to and sandwich the corresponding orifice line **107***b* in a plan view. In the present embodiment, a distance D1 from the orifice plate **212** to the recording sheet **502** is 1.6 mm. A distance D2 from the orifice plate **212** to the common electrode **401** (**402**) is 0.3 mm. Each common electrode **401**, **402** has a thickness T1 of 0.3 mm in the y direction. The common electrodes **401** and **402** are separated from each other by a distance of 1 mm.

As shown in FIG. **4** there are provided an alternate current (AC) power source **403** and a pair of direct current (DC) power sources **404**. The AC power source **403** outputs an electric voltage Vchg. As will be described later, the value of the electric voltage Vchg is changed among several different values in a predetermined frequency. Each of the DC power sources **404** outputs an electric voltage Vdef/2. With this configuration, an electric voltage of Vchg+VdefY/2 and Vchg−Vdef/2 are applied to the common electrodes **401** and **402**, respectively. The orifice plate **212** having the ejection surface **301** is connected to the ground.

As shown in FIG. **5**, the common electrodes **401**, **402** and the orifice plate **212** together generate a charging electric field E1 in a region near the orifice **201**. Because the orifice plate **212** is conductive and connected to the ground, the direction of the charging electric field E1 is parallel to the normal line of the orifice plate **212** as indicated by an arrow A1. The common electrodes **401** and **402** also generate a deflector electric field E2 having a direction from the common electrode **401** to the common electrode **402** as indicated by an arrow A2. That is, the deflector electric field E2 has the direction A2 perpendicular to the orifice-line direction **302**. The magnitude of the deflector electric field E2 is in proportion to the electric voltage Vdef. The electric voltage Vdef is maintained at 400V in this embodiment.

Because the orifice **201** is separated from both the electrodes **401** and **402** by the same distance, the electric voltage applied to an ink droplet **501**, which is about to be ejected, is in proportion to the electric voltage Vchg. Accordingly, at the time of ejection from the orifice **201**, the ink droplet **501** is charged with a voltage of Q which has a magnitude in proportion to the electric voltage Vchg and a polarity opposite to the electric voltage Vchg. In this way, the electric field E1 charges the ink droplet **501**.

After ejection, the flying speed of the ink droplet **501** is accelerated by the charging electric field E1. When the ink droplet **501** reaches between the common electrodes **401** and **402**, the deflector electric field E2 deflects the ink droplet **501** toward the direction A2 of the electric field E2 and changes its flying direction to a direction indicated by an arrow A3. Then, the ink droplet **501** impacts on the recording sheet **502** at a position **502***b* shifted in the direction A2 by a distance C from an original position **502***a* where the ink droplet **501** would have impacted if not deflected at all. The distance C between the actual impact position **502***b* and the original position **502***a* is referred to as deflection amount C hereinafter.

FIG. **6** shows a table indicating the relationships among the deflection amounts C (μm) and average flying speeds Vav (m/sec) obtained when the AC voltage Vchg are 200V, 100V, 0V, −100V, and −200V. The average flying speed Vav indicates an average flying speed of the ink droplet **501** from when the ink droplet **501** is ejected from the orifice **201** until impacts on the recording sheet **502**.

It should be noted that a flying time T from when the ink droplet **501** is ejected until when the ink droplet impacts on the recording sheet **502** is ignored in the explanation. This is because fluctuation in the deflection amount C within values that the deflection amount C takes during actual printing hardly varies the flying time T. A possible explanation for this is that when the deflection amount C is relatively large, a flying distance of the ink droplet **501** increases. However, in this case, the charging amount Q also increases, and this in turn increases acceleration rate cased caused by the charging electric field E1 and the deflecting electric field E2, thereby increasing the average speed Vav of the ink droplet **501**. Accordingly, the flying time T stays unchanged regardless of the deflection amount C.

Next, an x-y coordinate system used in this embodiment will be described while referring to FIG. **7**. The x-y coordinate system is defined on the recording sheet **502**, and includes a plurality of x-scanning lines **701** and a plurality of y-scanning lines **702**. The x-scanning lines **701** extend in the x direction and align at a uniform interval of dy in the y direction, which is referred to as “resolution interval dy”. On the other hand, the y-scanning lines **702** extend in the y direction and align at a uniform interval of dx in the x direction, which is referred to as “resolution interval dx”. These x-scanning lines **701** and y-scanning **702** lines intersect one another and define a plurality of grids **704** having grid corners **704***a*. The ink droplets **501** are controlled to impact on one of grid corners **704***a*, which is defined by a coordinate value (dx, dy). It should be noted that in the present embodiment, the recording sheet **502** is moved in the y direction during printing.

In the present embodiment, the recording head **107** is positioned above the recording sheet **502** while its ejection surface **301** faces and extends parallel to the recording sheet **502**. The distance between the recording sheet **502** and the ejection surface **301** is between 1 mm and 2 mm.

Next, a specific example of the present embodiment will be described while referring to FIG. **7**. In this example, tan θ is set to ¼. Also, the charging electric field E1 takes four different magnitudes, i.e., a deflection number n is **4**, so an ink droplet **501** ejected from a single orifice **201** is deflected by one of four deflection amounts C, and impacts on one of four impact positions **703**. Because it is desirable to decrease the deflection amount C, the four impact positions **703** are symmetrically arranged to the left and right sides of the orifice **201**.

Also, in the present example, two adjacent orifices **201** are separated in the x direction by two grids **704** (2dx). Accordingly, the nozzle interval in the y direction is 8dx (=2dx/tan θ).

Because the orifice pitch in the orifice-line direction **302** is set to **75** orifices/inch as described above, the resolution interval dx is 41 μm, so the resolutions of the printed image **114** in the x and y directions are both **619** dpi (1/dx and 1/dy, respectively).

Although the adjacent orifices **201** are separated by 2dx in the x direction, because ink droplets **501** ejected from a single orifice **201** hit on four different x-scanning lines **701**, a dot on every grid corners is formed by two ink droplets **501** ejected from two orifices **201**.

FIGS. **8**(*a*) to **8**(*c*) show relationships between the charging electric field E**1**, the ejection data **112**, and the impact positions **703**. In FIG. **8**(*a*), a sheet-feed time t**0**, t**1**, t**2**, . . . is a time duration required to move the recording sheet **502** by a single grid in the y direction (1dy), which is referred to as "dot frequency". The sheet-feed time is further divided into n dot-forming time segments t**00**, t**01**, t**02**, t**03**, t**10**, t**11**, t**12**, t**13**, t**20**, . . . , which is referred to as "deflected-dot frequency". In each dot-forming time segment, a single dot is formed by a single nozzle **107***a*. Because the deflection number n is 4 in this example, the dot-forming time segment is ¼ of the sheet-feed time.

As shown in FIGS. **8**(*a*) and **8**(*c*), the ejection data **112** is output for a dot (x**3**, y**0**) at the dot-forming time t**00**. As a result, as shown in FIG. **8**(*d*), an ink droplet **501** ejected from the orifice **201** is deflected rightward perpendicular to the orifice-line direction **302**, and impacts on a y-scanning line x**3** on the recording sheet **502**. At this time, the impact position **703** is on the grid corner (x**3**, y**0**).

At the subsequent dot-forming time t**01**, the magnitude of the charging electric field E**1** has been changed as shown in FIG. **8**(*b*), and the ejection data **112** for (x**2**, y**0**) is output. Accordingly, the ejected ink droplet **501** is deflected rightward and impacts on the y-scanning line x**2** as shown in FIG. **8**(*e*). Because the recording sheet **502** has been transported by a distance of 1dy/4 by this moment, the impact position **703** is on the grid corner (x**2**, y**0**). Then, at the dot-forming time of t**02**, the magnitude of the charging electric field E**1** has been changed as shown in FIG. **8**(*b*), and the recording sheet **502** has been moved by a distance of another 1dy/4. The ejection data **112** for (x**1**, y**0**) is output, and as shown in FIG. **8**(*f*), the ejected ink droplet **501** is deflected leftward perpendicular to the orifice-line direction **302** and impacts on the grid corner (x**1**, y**0**) on the y-scanning line x**1**. At the dot-forming time t**03**, the magnitude of the charging electric field E**1** has been changed as shown in FIG. **8**(*b*), and the ejection data **112** for (x**2**, y**0**) is output. Accordingly, as shown in FIG. **8**(*g*), the ejected ink droplet **501** is deflected leftward and impacts on the y-scanning line x**0**.

During the sheet-moving time t**1** and on, the same processes are performed, so dots are formed on every grid corner.

It should be noted that because the flying time T is constant regardless of the deflection amount C as described above, it is unnecessary to take the flying time T (sheet transporting speed) into consideration when determining the ink ejection timing. In actual printing, the recording sheet **502** is moved by a predetermined distance in the y direction while the flying time T. Therefore, it would be only necessary to be aware that all the actual impact positions **703** would shift by a predetermined distance in the y direction. Also, the timing of changing the magnitude of the charging electric field E**1** is set to the exact time of when the ink droplet **501** is generated, that is, when the ink droplet **501** is separated from remaining ink in the nozzle **107***a*. This can be achieved by setting the actual timing to a time a predetermined time duration after the ejection data **112** is output, that is, after the piezoelectric element is driven. This timing can be obtained through experiments.

Next, an example of ejection-deflection operation will be described while referring to FIG. **9**.

When printing is performed using all the nozzles **201**, two ink droplets **501** from different nozzles **201** forms one dot on respective grid corners **704***a*. Accordingly, it is possible to select which one of two nozzles **201** to use for forming a dot on a corresponding grid corner **704***a*. In an example of FIG. **9**, a dot (x**0**,y**0**) is formed by a nozzle N**1**. A dot (x**0**, y**1**) is formed by a nozzle N**2**. A dot (x**0**, y**2**) is formed by the nozzle N**1**, and a dot (x**0**, y**3**) is formed by the nozzle N**2**. By forming dots on a single y scanning line **702** by using two nozzles **201** in alternation in this manner, it is possible to prevent uneven color density appearing on an image in a form of banner extending in the y direction, which is due to uneven nozzle characteristics.

Next, a restored printing for when a nozzle **201** becomes defective will be described while referring to FIG. **10**. In this example, it is assumed that the nozzle N**2** becomes defective. When the nozzle N**2** becomes defective, dots (x**1**, y**0**), (x**0**, y**1**), (x**1**, y**2**), (x**0**, y**3**), (x**1**, y**4**), and on, which are originally allocated to the nozzle N**2**, are formed by the nozzle N**1**, and dots (x**3**, y**0**), (x**2**, y**1**), (x**3**, y**2**), (x**2**, y**3**), (x**3**, y**4**) and on, which are also originally allocated to the nozzle N**2**, are formed by the nozzle N**3**.

In this restored printing, dots can be formed on all grid corners **704***a* without using the defective nozzle N**2**. Although this operation is not useful for when two adjacent nozzles become defective, there is only a slight possibility that any one nozzle **201** becomes defective during printing, there is hardly a possibility that two adjacent nozzles **201** become defective, so that there is no need to take that possibility into consideration. Therefore, it can say that the above operation enables forming of dots on all grid corners **704***a*without using any defective nozzles **201**. In this case, the ejection data **112** is generated by the signal processing portion **101** in accordance with the current restored printing.

Next, an explanation will be provided for the switching of the printing while referring to FIGS. **1**, **11**, and **12** and also a table shown later. The ejection-deflection operations are when at least one nozzle is detected defective in a detection operation.

The detection unit **110** shown in FIG. **1** detects whether the printing is normal or defective, and outputs a detection signal to the detection-restoring unit **111**. Specifically, the detection unit **110** detects whether all the nozzles having performed ejection are normal or at least one of the nozzles having performed ejection is defective. If all the nozzles are normal, a detection signal of 1 is output. On the other hand, if at least one of the nozzles is defective, then a detection signal of 0 is output.

Upon reception of the detection signal of 0, the detection-restoring unit **111** outputs a restore signal to the signal processing portion **101**, commanding to restore the printing. The signal processing portion **101** changes a generation method of the ejection data **112** so as to generate the ejection data **112** that is adjusted for a restoring printing. It should be noted that the actual detection-restoring unit **111** is realized as one of the processes of the signal processing portion **101**. However, in the present example, the detection-restoring unit **111** is described as a component separated from the signal processing portion **101** so as to facilitate the explanation.

Next, the detection unit **110** is described. The detection unit **110** detects change in electric current conducted through a power source that generates the deflecting voltage Vdef of the charging voltage Vchg. As described above, a charged ink droplet from a normal nozzle **201** reaches the recording sheet without impacting on the electrode **401** nor **402**. Therefore, no electric current is conducted through the electrodes **401, 402**. However, an ink droplet ejected at an angle or a splashed minute ink droplet from a defective nozzle **201** impacts on the electrode **401** or **402**. Because these ink droplets are charged, electric current is conducted through the electrode **401, 402**. The detection unit **110** outputs the detection signal of 1 when detecting no current and the detection signal of 0 when detecting the current.

It should be noted that this detection method cannot detect ejection failure although it can detect angled ejection and splash. Usually, ejection failure is detected by a laser beam light or CCD sensor after test printing. However, the angled ejection or splash usually occurs before the nozzles become completely clogged. That is, the detection method of the present invention can detect presence of defective nozzles before these nozzles become incapable of ink ejection.

In the present detection, a condition register S is used. The register S is a memory region with a specific function secured within the signal processing portion **101**. The condition register S includes a plurality of elements for respective nozzles **201**. In this example, it is assumed that n nozzles **201** and accordingly n elements are provided. Each of the n elements takes three condition values 0, 1, 2, wherein the condition value of 0 represents that a corresponding nozzle is defective, the condition value of 2 represents that a corresponding nozzle is normal, and the condition value of 1 represents that a condition of a corresponding nozzle is unknown. Usually, all the elements of the register S initially take the condition value of 1, indicating unknown. Needless to say, if there is any nozzle whose condition is known, the corresponding value takes either 0 or 2, instead.

Ejection data D is detected by the detection-restoring unit **111** before ejection. The ejection data D includes n bits for the respective n nozzles. Each bit takes an ejection value of 1 for ejection or a non-ejection value of 0 for non-ejection. When the signal processing portion **101** generates one-page-worth of the ejection data **112**, the one-page worth of or a portion of the one-page-worth of the ejection data D is stored in the detection-restoring unit **111**, and the detection-restoring unit **111** refers to thus stored ejection data D at the time of detection.

The detection-restoring unit **111** does not perform the detection of the ejection data D every time when the ejection is performed because it is time consuming. In the present embodiment, the detection is performed every time the ejection is performed 1,024 times, or about 5 Hz. That is, the detection-restoring unit **111** stores the ejection data D once every 1,024 times the signal processing portion **101** generates the ejection data **112**.

At the time of the selective ink ejection, when the detection unit **110** outputs the detection signal of 1 indicating normal ejection, this means that all the nozzles having performed the ink ejection, that is, the nozzles corresponding to the ejection value of 1, are normal. On the other hand, when the detection unit **110** outputs the detection signal of 0 indicating defective ejection, this means that at least one of the nozzles having performed the ejection is defective. However, as described above, a defective nozzle cannot be identified by simply detecting the conducted electric current.

In the present embodiment, the defective nozzle is identified in a detection process represented by a flowchart of FIG. **11**. Details will be described next.

It should be noted that in the present example it is assumed that the condition of all the n nozzles are unknown, and also that there is no defect register E (Hereinafter referred to as 'defective register') at the beginning.

When the routine is started in **S1101**, first in **S1102** all the condition values of the condition register S are initialized to 1 that represents the unknown condition.

Next, in **S1103**, it is determined whether or not there is no nozzle with unknown condition, i.e., whether or not the condition register S has any element with the condition value of 1. If not (**S1103**:NO), the present process is brought to a normal end in **S1104**.

On the other hand, if so (**S1103**:YES), then the process proceeds to **S1105**. In **S1105**, detection restoring unit **111** gets the ejection data D from the signal processing portion **101**, and gets the detection signal from detection unit **110**. Then, in **S1106**, it is judged whether or not the printing is normal based on the signal from the detection unit **110**.

If the printing is defective (**S1106**:NO), this means that there is at least one defective nozzle among the nozzles with the ejection value of 1, then the process proceeds to **S1107**. In **S1107**, the ejection data D is updated based on the condition register S, where the values in the ejection data D are set to 0 for the normal nozzles, that is the nozzles with the condition value of 2, and the values for the others are maintained the same. Next in **S1108**, the updated ejection data D is compared with a set of defective registers E to judge whether or not there is any defective register E that matches the updated ejection data D. If so (**S1108**:YES), the process returns to **S1103**. On the other hand, if **S1108** results in a negative determination (**S1108**:NO), and then in **S1109** the updated ejection data D is set to a defective register E and added to the set of the defective registers E. The defective register E is generated in this manner and increases its number.

Next, in **S1110**, the newly added defective register E is set as an argument, and a restoring process is executed for the defective register E. FIG. **12** shows a flowchart representing the restoring process.

When the restore process is started, first in **S1201** it is detected whether or not the number of the element in the defective register E that has the value of 1 is only one. If not (**S1201**:NO), the present routine is ended. On the other hand, if so (**S1201**:YES), this means that the nozzle that corresponds to the element with the value of 1 is the one that is defective. Then in **S1202**, the condition register S is updated such that the condition value for the defective nozzle is set to 0 indicating the defective condition.

Next in **S1203**, it is determined whether or not the detected defective nozzle is adjacent to an existent defective nozzle which has been detected earlier. If so (**S1203**: YES), then in **S1204** the present routine is brought to an end. That is, because the above-described restored printing is not useful in this case as described above, the printing is stopped, and then any restoring operation, such as cleaning operation, is performed.

As described above, there is hardly a possibility that two adjacent nozzles become defective during the printing. Also, even if a plurality of nozzles becomes defective, printing can be properly performed as long as the plurality nozzles are not adjacent to one another.

If **S1203** results in a negative determination (**S1203**:NO), then in **S1205**, restored printing is performed without using the defective nozzle. In **S1206**, all the defective registers E so that the condition value for the detected defective nozzle is **1** is deleted from the set of the defective registers E. Then, the process returns.

On the other hand, if **S1106** results in a positive determination (**S1106**:YES), this means that all the nozzles with the ejection value of 1 are normal. Then, in **S1111**, the condition register S is updated so that the condition values for these normal nozzles are set to 2. Next, in **S1112**, it is determined whether or not any unprocessed defective register E exists in the set of the defective registers E. If not (**S1112**:NO), the process returns to **S1103**. If so (**S1112**:YES), then in **S1113** one unprocessed defective register E is retrieved, and in **S1114** the defective register E I updated so that the value for the normal nozzle is set to 0. Then, in **S1115**, the adjustment process shown in FIG. **12** is executed, and the process returns to **S1112**. The same process is repeated for any unprocessed defective register E.

A specific example of the above-described detecting process will be described while referring to a following table T. Explanation will be provided while referring to line numbers (No.) in the left most column of the table 1. In the present example, it is assumed that the ink jet recording device is formed with eight nozzles in order to simplify the explanation. Also, it is assumed that second and seventh nozzles among the eight nozzles are defective as indicated at No. **1** of the table 1. Needless to say, the defectiveness of the second and seventh nozzles is unknown before the detecting process.

TABLE T

No	STEP	ITEM	REGISTER	VALUES 12345678	NUMBER OF 1	DETECTION RESULT	DESCRIPTION
1		nozzle conditions		20222202	8		0: Defective 2: Normal
		(initially unknown)					2: Normal 1: Unknown 0: Defective
2	1102	condition register S (initial value)	S	11111111			
3	1105	ejection data D	D	01110001			0: Nonejection 1: Ejection
		detection result				1	sensor result (1: Defective 0: Normal)
4	1106	defective					
5	1107	update ejection data D	D	01110001			normal nozzle (Sn = 2) → 0
6	1109	defective register E1/number of 1	E1	01110001	4		number is not 1 → skip
7	1105	ejection data D	D	01011101			0: Nonejection 1: Ejection
		detection result				1	sensor result (1: Defective 0: Normal)
8	1106	defective					
9	1107	update ejection data D	D	01011101			normal nozzle (Sn = 2) → 0
10	1108	no D in defective registers					
11	1109	defective register E2/number of 1	E2	01011101	5		not 1 → skip
12	1105	ejection data D	D	00010101			0: Nonejection 1: Ejection
		detection result				0	sensor result (1: Defective 0: Normal)
13	1106	normal					
14	1111	update condition register S	S	11121212			normal nozzle → 2
15	1114	defective register E1/number of 1	E1	01100000	2		normal nozzle → 0, not 1 → skip
16	1114	defective register E2/number of 1	E2	01001000	2		normal nozzle → 0, not 1 → skip
17	1105	ejection data D	D	01010101			0: Nonejection 1: Ejection
		detection result				1	sensor result (1: Defective 0: Normal)
18	1106	defective					
19	1107	update ejection data D	D	01000000			normal nozzle (Sn = 2) → 0
20	1108	no D in defective registers					
21	1109	defective register E3/number of 1	E3	01000000			is 1 → restore
22	1201	E3/number = 1 → restore			1		
23	1202	update condition register S	S	10121212			defective nozzle → 0, restore
24	1206	delete defective register E					delete E including defective nozzle
25	1105	ejection data D	D	00001110			0: Nonejection 1: Ejection
		detection result				1	sensor result (1: Defective 0: Normal)
26	1106	defective					
27	1107	update ejection data D	D	00001010			normal nozzle (Sn = 2) → 0
28	1108	no D in defective registers					
29	1109	defective register E1/number of 1	E1	00001010	2		normal nozzle → 0, not 1 → skip
30	1105	ejection data D	D	00101100			0: Nonejection 1: Ejection
		detection result				0	sensor result (1: Defective 0: Normal)
31	1106	normal					
32	1111	condition register S	S	10222212			normal nozzle → 2
33	1114	defective register E1/number of 1	E1	00000010	1		normal nozzle → 0, is 1 → restore
34	1201	E1/number = 1 → restore					
35	1202	condition register S	S	10222202			defective nozzle → 0, restore
36	1206	delete defective register E					delete E including defective nozzle
37	1105	ejection data D	D	10010000			0: Nonejection 1: Ejection
		detection result				0	sensor result (1: Defective 0: Normal)
38	1106	normal					
39	1111	update condition register S	S	20222202			normal nozzle → 2
40	1112						no set of defective registers E
41	1103	number of 1	S	20222202	0		
		within condition register S					
42	1104						normal end

First, at No. **2**, the process of **S1102** in FIG. **11** is executed, and all the elements of the condition register S are initialized to the condition value of 1, the condition value of 1 indicating unknown condition. Accordingly, **S1103** results in a negative determination (**S1103**:NO). Next, at No. **3**, the process of **S1105** is executed to perform selective ejection. The ejection data D at this time is "01110001", for example. Also in **S1105**, detection signal is received from the detection unit **110**. In this example, the detection signal of **1** is received, and so **S1106** results in a negative determination (**S1106**:NO), i.e., defective, at No. **4**. At No. **5**, the ejection data D is updated based on the condition register S in **S1107**. In this example, the ejection data D is unchanged at this time.

Because there is no defective register E identical to the updated ejection data D (**S1108**:NO), the updated ejection data D is set as a defective register E1 and added to a set of defective registers E (**S1109**) at No. **6**. Because the defective register E1 includes four values of 1 at this time, **S1201** results in a negative determination (**S1201**:NO), and the process returns to **S1103**. The same processes are repeated at No. **7** through No. **11**.

At No. **12** in **S1105**, the detection signal of 0 is received, so it is judged the normal ejection in **S1106** at No. **13** (**S1106**:YES). Because the ejection data D at No. **12** has the ejection value of 1 for the fourth, sixth, and eighth nozzles, these nozzles are determined to be normal, and the condition values of the condition register S for these normal nozzles are set to 2 in **S1111** at No. **14**. In **S1114** at No. **15**, the defective register E1 shown at No. **6** is updated as shown at No. **15**, where the condition values for the normal nozzles are changed from 1 to 0. The resultant values are "01100000" as shown at No. **15**. Because there are two condition values of 1, **S1201** results in a negative determination (**S1201**:NO), and so the process returns to **S1112**. Then, the same process is executed to the subsequent defective register E2 in **S1113** and **S1114**. No. **16** shows the defective register E2 updated from the defective register E2 of No. **11** by replacing the value of 1 to 0 for the normal nozzles. In this case also, the number of the condition values of 1 is not one, but two, so **S1201** results in a negative determination, and the process returns to **S1112**. Because there is no more unprocessed defective register E (**S1112**:NO), the process returns to **S1103**.

At No. **17** through No. **21**, the processes of **S1105** through **S1109** are performed in the same manner. At No. **22**, because the defective register E3 has only one value of 1, it is determined that the second nozzle, in this example, is defective. **S1201** results in an affirmative determination at No. **22** (**S1201**:YES), and then in **S1202**, the condition register S is updated so that the condition value for the defective nozzle (second nozzle) is changed to 0. In this case, the updated register S has the values of "10121212" as shown at No. **23**. Because there is no adjacent defective nozzle in this example (**S1203**:NO), it is stopped using the defective nozzle, and normal nozzles next to the defective nozzle cover up the defective nozzle and form dots, which are originally allocated to the defective nozzle, instead of the defective nozzle. Then, all the defective registers E having the condition value of 1 for the defective nozzle (second nozzle) are deleted in **S1206** at No. **24**. In this example, the defective registers E1, E2, and E3 are all deleted.

When the same process is repeatedly executed, the remaining seventh nozzle is detected to be defective in **S1114** at No. **15**, and eventually at No. **41** it is determined in **S1103** that the condition register S includes no condition value of 1. Then, the process is brought to the normal end in **S1104**.

Although not described in the above example, it may be determined in **S1203** that the defective nozzle is in adjacent to another defective nozzle, and then the defective end may result. In this case, the printing is stopped, and the restoring process is executed as described above.

According to the present embodiment, when a nozzle becomes defective during the printing, the defective nozzle is automatically detected and proper printing can be restored without a need to stop the printing.

Next, a detecting process according to a second embodiment of the present invention will be described while referring to a flowchart shown in FIG. **13**. In the above-described first embodiment, the restoring operation is performed only after the number of condition values of 1 within the defective register E becomes one. However, when two or more nozzles become defective and when these defective nozzles are those that highly likely perform ink ejection at the same time, the number of condition values of 1 will not easily reach one. In this case, it takes relatively a long period of time before the restoring operation starts. Moreover, the accumulated number of the defective registers E becomes so large that the data value may exceed the capacity of the memory, resulting in memory overflow.

The restoring process of the second embodiment overcomes such a problem. Specifically, when the number of the defective registers E reaches a predetermined number, the following process is executed. Also, there is provided a defective additional memory ES including a plurality of elements for the respective nozzles. Each of the elements includes a plurality of bits, and functions as a memory for storing an element value. Details will be described below.

In the flowchart of FIG. **13**, when the process starts in **S1301**, all element values of the defective additional memory ES are initialized to 0 in **S1302**. Next in **S1303**, it is detected whether or not there is any unprocessed defective register E. If so (**S1303**:YES), then in **S1304**, one unprocessed defective register E is retrieved. Then, in **S1305**, the condition values of the retrieved defective register E are added to the corresponding elements of the defective additional memory ES, and the process returns to **S1303**. The same processes of **S1304** and **S1305** are executed to all unprocessed defective registers E. When **S1303** results in a negative determination (**S1303**:NO), then in **S1306**, the ejection data D is received. When the received ejection data D have only the values of 0, indicating no ejection, (**S1307**:YES), then the process proceeds to **S1308**. In **S1308**, a nozzle corresponding to an element of the defective additional memory ES with the largest value is identified, and the value of the ejection data D for the detected nozzle is changed from 0 to 1 so that only the detected nozzle performs the ejection. In this way, the ejection data D is updated. Next, in **S1309** the ejection is performed based on the updated ejection data D, and the detection signal is received from the detection unit **110**. At this time, one dot is formed (test printed) on a recording sheet although no dot is supposed to be formed. However, degradation in the printed result due to the one unnecessary dot is far less than that caused by defective ink ejection from a defective nozzle, and such degradation is small enough to ignore. Then, in **S1310**, it is determined whether or not the ejection is normal. If defective (**S1310**:NO), the same operations as that of **S1107** through **S1110** in FIG. **11** are executed in **S1312**, and the process is ended in **S1313**. On the other hand, if normal (**S1310**:YES), the same processes of **S1111** through **S1115** in FIG. **11** are executed in **S1311**, and the process is ended in **S1313**.

As described above, according to the second embodiment, the test printing is performed where a single dot is formed by a single nozzle. Because the single nozzle is highly likely the defective nozzle, the defective nozzle can be promptly detected in an effective manner. Accordingly, the defective nozzle is stopped from being used at an earlier stage, so that degradation of an image quality can be reduced. Further, the number of the defective registers E is greatly reduced regardless of whether the tested nozzle is normal or defective, so that the memory overflow can be prevented.

Next, a third embodiment of the present invention will be described while referring to FIG. **14**. In this embodiment, the electric-current detection is performed by using a laser beam.

The ink jet head **107** of the third embodiment includes a laser-beam generator **1501** and a laser-beam receptor **1504** shown in FIG. **15** at the ends of corresponding nozzle line for generating a laser beam **1401** or **1402** shown in FIG. **14** between the laser-beam generator **1501** and the laser-beam receptor **1504**. The laser-beam generator **1501** includes a well-known semiconductor laser **1502** and a collimate lens **1503**. The laser-beam receptor **1504** includes a well-known photodiode **1504** and a signal detection circuit (not shown). The axis of the laser beam **1401**, **1402**, is parallel to the nozzle line direction **302**. A plurality of concentric circles of the laser beam **1401**, **1402** indicates its strength distribution. A charged splash from a nozzle **201** flies to the electrode **401** as indicated by an arrow **1403** and impacts thereon. Because the laser beam **1401** intersects the path **1403**, the splash flying along the path **1403** blocks the laser beam **1401**, so that the amount of the laser beam **1401** received be the laser-beam receptor **1504** reduces. Accordingly, the occurrence of splash can be detected by detecting change in the amount of the laser beam **1401**, **1402** reaching the laser-beam receptor **1504**. Because the splash flies to the electrode **402** in the same manner, only one of the laser beams **1401** and **1402** is necessary for the detection.

In this method also, a defective nozzle cannot be identified by merely detecting the change in the laser beam amount, although the occurrence of defective ejection can be detected. However, the same process as that of the first or second embodiment can be executed in the third embodiment also in order to identify the defective nozzle.

According to the third embodiment, ink droplets ejected at angle and splashed minute droplets can be detected even when these do not reach and impact on the electrodes **401**, **402**, so a nozzle, which is not completely defective but incapable of proper ejection, can also be detected. Accordingly, the above restoring operation can be performed at an earlier stage, and so the degradation of the image quality can be minimized.

As described above, according to the present invention, the electrodes for generating a charging electric field and deflector electric field can be provided common to a plurality of nozzles. This provides a highly reliable multi-nozzle head. Also, because ink droplet ejections are performed at constant intervals, a maximum ejection rate available for the nozzles can be used. Further, it is possible to perform a multiple ejection, where a single dot is formed by a plurality of ink droplets from different nozzles, and so the reliability can be increased as needed. Moreover, the ink droplet ejection in a non-rectangular coordinate system with honeycomb shape is also possible. In this case, the amount of overlapping regions among adjacent dots can be minimized, so the ink consumption can be reduced.

While some exemplary embodiments of this invention have been described in detail, those skilled in the art will recognize that there are many possible modifications and variations which may be made in these exemplary embodiments while yet retaining many of the novel features and advantages of the invention.

Although in the above-described embodiment, the orifices **201** are aligned in the pitch of **75** orifices/inch, the nozzles **107***a* can be aligned in the pitch of **150** orifices/inch. In this case, a resolution will be twice the above-described resolution. Also, the number of nozzles **107***a* (orifices **201**) is not limited to **128**.

Also, the present invention can be also applied to an ink jet recording device where printing is performed while a recording head is moved and a recording sheet stays still rather than where the printing is performed while the recording sheet is moved and the recording sheet stays still.

Further, the present invention can also be applied to bubble jet recording device where an air bubble is generated by applying head, and ejecting ink by utilizing the pressure of the generated air bubble.

What is claimed is:

1. An ink jet recording device comprising:

a head formed with a plurality of nozzles through which ink droplets are selectively ejected based on ejection data during actual printing;

electrodes that generate a charging electric field for charging the ink droplets ejected from the head and a deflector electric field for deflecting the ink droplets charged by the charging electric field, the electrodes being provided common to the plurality of nozzles;

first detecting means for detecting whether all of selected nozzles through which ink droplets are ejected based on the ejection data are normal or at least one of the selected nozzles is defective;

identifying means for automatically identifying, without performing test-pattern printing while the actual printing is not being performed, a defective nozzle while the head is continuously performing the actual printing based on the ejection data when the first detecting means detects that the ejection is performed defectively.

2. The ink jet recording device according to claim **1**, further comprising restoring means for automatically restoring proper printing of the head when the identifying means identifies the defective nozzle.

3. The ink jet recording device according to claim **2**, further comprising a memory storing a defect register including a plurality of elements each taking one of a first value indicating a defectiveness of a corresponding nozzle and a second value indicating normalness of a corresponding nozzle, wherein the identifying means updates the defect register based on the ejection data, and the restoring means restores the proper printing of the head when only one of the elements in the defect register takes the first value.

4. The ink jet recording device according to claim **3**, wherein the memory further stores a condition register including a plurality of elements for respective nozzles, each of the elements takes one of a normal-condition value indicating normal condition of the corresponding nozzle, a defective-condition value indicating defective condition of the corresponding nozzle, and an unknown-condition value indicating unknown condition of the corresponding nozzle.

5. The ink jet recording device according to claim **4**, wherein the identifying means updates the condition register based on the ejection data when the first detecting means detects that the ejection is performed normally.

6. The ink jet recording device according to claim **4**, wherein the identifying means updates the condition register based on the ejection data when the ejection is detected as normal.

7. The ink jet recording device according to claim **4** wherein the restoring means rearranges the dot allocation to not use the defective nozzle identified by the identifying means.

8. The ink jet recording device according to claim **3**, in the head selectively ejects ink droplets through the nozzles to form dots on a recording medium, the dots being allocated to corresponding nozzles, and the restoring means restores the proper printing of the head by rearranging the dot allocation to the plurality of nozzles.

9. The ink jet recording device according to claim **1**, wherein the identifying means includes searching means for searching a nozzle from the plurality of nozzles that is most likely the defective nozzle and second detecting means for detecting ejection data based on which the plurality of nozzles of the head eject no ink droplet, and the restoring means controls the head to eject an ink droplet only from the nozzle searched by the searching means when the second detection means detects the ejection data.

10. The ink jet recording device according to claim **9**, further comprising a memory that stores and additional memory that has values for respective nozzles, wherein the identifying means accumulates values of the ejection data to the corresponding values of the additional memory, and the searching means searches the nozzle that is most likely the defective nozzle based on the values of the additional memory.

11. The ink jet recording device according to claim **1**, wherein the first detecting means detects whether the ejection is performed normally or defectively by detecting an amount of an electric current conducted through the electrodes.

12. The ink jet recording device according to claim **1**, further comprising a laser beam generator that generates a laser beam and a laser beam receptor that receives the laser beam, wherein the first detecting means detects the amount of the laser beam received by the laser beam receptor.

13. The ink jet recording device according to claim **12**, wherein the first detecting means detects that the ejection is performed defectively when the amount of the laser beam received by the laser beam receptor is decreased.

14. The ink jet recording device according to claim **13**, wherein the plurality of nozzles are aligned in a line in a line direction, and the laser beam extends parallel to the line direction.

15. A method of detecting a defective nozzle among a plurality of nozzles formed in a head of an ink jet recording device that includes the head and a pair of electrodes for generating a deflection electric field common to the plurality of nozzles, comprising the steps of:

a) detecting whether all of selected nozzles through which ink droplets are ejected based on ejection data during actual printing are normal or at least one of the selected nozzles is defective; and

b) identifying, without performing test-pattern printing while the actual printing is not being performed, a defective nozzle among the plurality of nozzles while the head is continuously performing the actual printing based on the ejection data when the ejection is detected as defective in step a).

16. The detecting method according to claim **15**, further comprising the steps of:

c) stopping use of the nozzle that is identified defective in step b); and

d) reallocating dots, which were originally allocated to the defective nozzle, to a nozzle other than the defective nozzle.

17. The detecting method according to claim **15**, wherein the ejection is detected as defective in the step a) when electric current conducted through the electrodes is increased.

18. The detecting method according to claim **15**, wherein the ejection is detected as defective in the step a) when an amount of a laser beam received by a laser beam receptor is decreased, the laser beam extending parallel to, and displaced from a direction in which a plurality of nozzles are aligned in a line.

19. The detecting method according to claim **15**, wherein the step b) includes the steps of:

e) generating a defect register having elements for respective nozzles based on ejection data;

f) detecting whether the number of elements of the defect register that have a defect-condition value indicating that the corresponding nozzle is defective is zero or at least one; and

g) identifying the nozzle that corresponds to the element of the defect register with the defect-condition value when the number is determined one in the step f).

20. The detecting method according to claim **15**, wherein the step b) includes the steps of:

h) searching one of the plurality of nozzles that is most likely the defective nozzle;

i) searching ejection data based on which no ejection is performed through any of the plurality of nozzles; and

j) updating the ejection data searched in the step **1)** such that a non-ejection value of the ejection data corresponding to the nozzle searched in the step h) is changed to an ejection value.

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